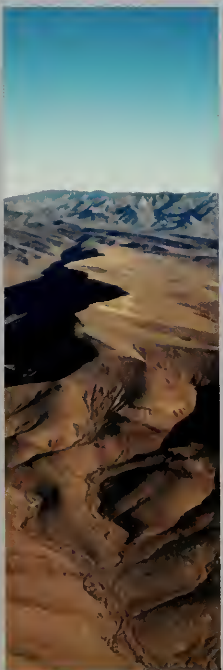


Draft

Environmental Impact Statement

for a
Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

Summary

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

DOE/EIS-0250D

July 1999

ACRONYMS AND ABBREVIATIONS

To ensure a more reader-friendly document, the U.S. Department of Energy (DOE) limited the use of acronyms and abbreviations in this environmental impact statement. In addition, acronyms and abbreviations are defined the first time they are used in each chapter or appendix. The acronyms and abbreviations used in the text of this document are listed below. Acronyms and abbreviations used in tables and figures because of space limitations are listed in footnotes to the tables and figures.

BWR	boiling-water reactor
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy (also called *the Department*)
EIS	environmental impact statement
EPF	energy partition factor
FR	*Federal Register*
LCF	latent cancer fatality
MTHM	metric tons of heavy metal
NWPA	Nuclear Waste Policy Act, as amended
OCRWM	Office of Civilian Radioactive Waste Management
PM_{10}	particulate matter with an aerodynamic diameter of 10 micrometers or less
$PM_{2.5}$	particulate matter with an aerodynamic diameter of 2.5 micrometers or less
PWR	pressurized-water reactor
UFSAR	Updated Final Safety Analysis Report
USC	United States Code

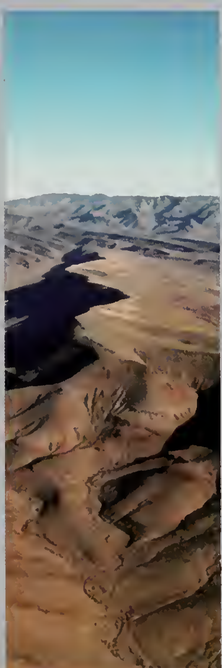
UNDERSTANDING SCIENTIFIC NOTATION

DOE has used scientific notation in this EIS to express numbers that are so large or so small that they can be difficult to read or write. Scientific notation is based on the use of positive and negative powers of 10. The number written in scientific notation is expressed as the product of a number between 1 and 10 and a positive or negative power of 10. Examples include the following:

Positive Powers of 10
$10^1 = \times 1 = 10$
$10^2 = 10 \times 10 = 100$
and so on, therefore,
$10^6 = 1{,}000{,}000$ (or 1 million)

Negative Powers of 10
$10^{-1} = 1/10 = 0.1$
$10^{-2} = 1/100 = 0.01$
and so on, therefore,
$10^{-6} = 0.000001$ (or 1 in 1 million)

Probability is expressed as a number between 0 and 1 (0 to 100 percent likelihood of the occurrence of an event). The notation 3×10^{-6} can be read 0.000003, which means that there are three chances in 1,000,000 that the associated result (for example, a fatal cancer) will occur in the period covered by the analysis.



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COVER SHEET

RESPONSIBLE AGENCY: U.S. Department of Energy (DOE)

TITLE: Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada

CONTACT: For more information on this Environmental Impact Statement (EIS), write or call:

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The EIS is also available on the Internet at the Yucca Mountain Project website at *http://www.ymp.gov* and on the DOE National Environmental Policy Act (NEPA) website at *http://tis.eh.doe.gov/nepa/*.

For general information on the DOE NEPA process, write or call:

Carol M. Borgstrom, Director
Office of NEPA Policy and Assistance (EH-42)
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585
Telephone: (202) 586-4600, or leave a message at (800) 472-2756

ABSTRACT: The Proposed Action addressed in this EIS is to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain in southern Nevada for the disposal of spent nuclear fuel and high-level radioactive waste currently in storage at 72 commercial and 5 DOE sites across the United States. The EIS evaluates (1) projected impacts on the Yucca Mountain environment of the construction, operation and monitoring, and eventual closure of the geologic repository; (2) the potential long-term impacts of repository disposal of spent nuclear fuel and high-level radioactive waste; (3) the potential impacts of transporting these materials nationally and in the State of Nevada; and (4) the potential impacts of not proceeding with the Proposed Action.

PUBLIC COMMENTS: A 180-day comment period on this Draft EIS begins with the publication of the Environmental Protection Agency Notice of Availability in the *Federal Register*. DOE will consider comments received after the end of the 180-day period to the extent practicable. DOE will hold public meetings to receive comments on the Draft EIS at the times and locations to be announced in local media and a DOE Notice of Availability in the *Federal Register*. Written comments can also be submitted by U.S. mail to Wendy R. Dixon at the above address, or via the Internet at *http://www.ymp.gov*.

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OVERVIEW

The purpose of this environmental impact statement (EIS) is to provide information on potential environmental impacts that could result from a Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at the Yucca Mountain site. The potential repository would be located in Nye County, Nevada. The EIS also provides information on the potential environmental impacts from an alternative referred to as the No-Action Alternative, under which there would be no development of a geologic repository at Yucca Mountain.

U.S. Department of Energy Actions

The Nuclear Waste Policy Act, enacted by Congress in 1982 and amended in 1987, establishes a process leading to a decision by the Secretary of Energy on whether to recommend that the President approve Yucca Mountain for development of a geologic repository. As part of this process, the Secretary of Energy is to:

- Undertake site characterization activities at Yucca Mountain to provide information and data required to evaluate the site.
- Prepare an EIS.
- Decide whether to recommend approval of the development of a geologic repository at Yucca Mountain to the President.

The Nuclear Waste Policy Act, as amended (the EIS refers to the amended Act as the NWPA), also requires the U.S. Department of Energy (DOE) to hold hearings to provide the public in the vicinity of Yucca Mountain with opportunities to comment on the Secretary's possible recommendation of the Yucca Mountain site to the President. These hearings would be separate from the public hearings on the Draft EIS required under the National Environmental Policy Act. If, after completing the hearings and site characterization activities, the Secretary decides to recommend that the President approve the site, the Secretary will notify the Governor and legislature of the State of Nevada accordingly. No sooner than 30 days after the notification, the Secretary may submit a recommendation to the President to approve the site for development of a repository.

If the Secretary recommends the Yucca Mountain site to the President, a comprehensive statement of the basis for the recommendation, including the Final EIS, will accompany the recommendation. This Draft EIS has been prepared now so that DOE can consider the Final EIS, including the public input on the Draft EIS, in making a decision on whether to recommend the site to the President.

Presidential Recommendation and Congressional Action

If, after a recommendation by the Secretary, the President considers the site qualified for application to the U.S. Nuclear Regulatory Commission for a construction authorization, the President will submit a recommendation of the site to Congress. The Governor or legislature of Nevada may object to the site by submitting a notice of disapproval to Congress within 60 days of the President's action. If neither the Governor nor the legislature submits a notice within the 60-day period, the site designation would become effective without further action by the President or Congress. If, however, the Governor or the legislature did submit such a notice, the site would be disapproved unless, during the first 90 days of continuous session of Congress after the notice of disapproval, Congress passed a joint resolution of repository siting approval and the President signed it into law.

Actions To Be Taken After Site Designation

Once a site designation became effective, the Secretary of Energy would submit to the Nuclear Regulatory Commission a License Application, based on a particular facility design, for a construction authorization within 90 days. The NWPA requires the Commission to adopt the Final EIS to the extent practicable as part of the Commission's decisionmaking on the License Application.

Decisions Related to Potential Environmental Impacts Considered in the EIS

This EIS analyzes a Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The EIS also analyzes a No-Action Alternative, under which DOE would not build a repository at the Yucca Mountain site, and spent nuclear fuel and high-level radioactive waste would remain at 72 commercial and 5 DOE sites across the United States. The No-Action Alternative is included in the EIS to provide a baseline for comparison with the Proposed Action. DOE has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative to inform the Secretary of Energy's determination whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. In making that determination, the Secretary would consider not only the potential environmental impacts identified in this EIS, but also other factors as provided in the NWPA.

As part of the Proposed Action, the EIS analyzes the potential impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. This analysis includes information on such matters as the comparative impacts of truck and rail transportation, alternative intermodal (rail to truck) transfer station locations, associated heavy-haul truck routes, and alternative rail transport corridors in Nevada. Although it is uncertain at this time when DOE would make any transportation-related decisions, DOE believes that the EIS provides the information necessary to make decisions regarding the basic approaches (for example, mostly rail or mostly truck shipments), as well as the choice among alternative transportation corridors. However, follow-on implementing decisions, such as selection of a specific rail alignment within a corridor, or the specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul routes, would require additional field surveys, state and local government consultations, environmental and engineering analyses, and National Environmental Policy Act reviews.

S.1 The National Environmental Policy Act Process

The Department of Energy will evaluate whether to recommend to the President an action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. An essential element of the DOE evaluation is a thorough understanding of the potential environmental impacts that could occur as a result of a decision by the President to implement the Proposed Action. The National Environmental Policy Act provides Federal agency decisionmakers with a process to consider potential environmental consequences (beneficial and adverse) of proposed actions before agencies make decisions. In following this process, DOE has prepared this *Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* to provide the necessary background, data, and analyses to help decisionmakers and the public understand the potential environmental impacts of the proposed repository.

ENVIRONMENTAL CONSEQUENCES

In its regulations implementing the procedural provisions of the National Environmental Policy Act, the Council on Environmental Quality requires that an EIS include a discussion of the *environmental consequences* of the Proposed Action and alternatives. The discussion of environmental consequences includes:

- Environmental *impacts* or *effects* (impacts are synonymous with effects under the regulations)
- Any adverse environmental impacts that cannot be avoided
- The relationship between short-term uses of the environment and the maintenance and enhancement of long-term productivity
- Any irreversible or irretrievable commitment of resources.

The NWPA addresses very specifically how the National Environmental Policy Act requirements should be applied for the proposed Yucca Mountain repository. In particular, the NWPA specifies that it is not necessary to consider in the EIS the need for a repository, alternatives to geologic disposal, or alternative sites to Yucca Mountain. Although the Act does not require an evaluation of alternatives to a repository in this EIS, DOE evaluated the No-Action Alternative to provide a baseline for comparison with the Proposed Action.

DOE is distributing this Draft EIS to the general public, including stakeholders—the organizations and individuals who have indicated an interest—and to Federal, state, local, and Tribal governments. During the comment period, organizations and individuals will be able to comment on this Draft EIS in a variety of ways (public hearings, mail, facsimile, Internet). DOE will provide information on the locations, dates, and times of the public meetings in the

COMMENTS

DOE encourages comments on the Draft Yucca Mountain Repository EIS. Please submit your comments at a public hearing on the Draft EIS or

by mail to: Wendy R. Dixon, EIS Project Manager
Yucca Mountain Site Characterization Office
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
P.O. Box 30307, Mail Stop 010
North Las Vegas, Nevada 89036-0307

by facsimile to: 1-800-967-0739
by the Internet at: *http://www.ymp.gov*

Federal Register; in local newspapers; on radio and television stations; and on the EIS web site (*http://www.ymp.gov*).

DOE will consider timely comments it receives on the Draft EIS during its preparation of the Final EIS, which it plans to issue in 2000, and will consider comments it receives after the close of the prescribed comment period to the extent practicable.

S.2 Purpose and Need for Action and Background

S.2.1 PURPOSE AND NEED

For many years civilian and defense-related activities have produced spent nuclear fuel and high-level radioactive waste. These materials have accumulated—and continue to accumulate—at 72 commercial and 5 DOE sites across the United States. Figure S-1 shows the locations of these sites and Yucca Mountain.

In passing the Nuclear Waste Policy Act in 1982, Congress affirmed that the Federal Government is responsible for the permanent disposal of spent nuclear fuel and high-level radioactive waste. To that end, Congress has directed the Secretary of Energy to determine whether to recommend that the President approve the Yucca Mountain site for development of a repository for the permanent disposal of these materials.

S.2.2 BACKGROUND

DOE is responsible for implementing a permanent solution for the management of spent nuclear fuel and high-level radioactive waste. *Spent nuclear fuel* is fuel that has been withdrawn from a nuclear reactor following irradiation; it consists mostly of uranium, and is usually intensely radioactive because it also contains a high level of radioactive nuclear fission products. Commercial spent nuclear fuel was used in civilian nuclear reactors to produce electricity. The majority of DOE spent nuclear fuel comes from defense production reactors, naval propulsion plant reactors, test and experimental reactors. In addition to conventional uranium fuel, DOE is responsible for the disposition of weapons-usable plutonium that is surplus to national security needs. This EIS has included surplus weapons-usable plutonium that has been converted to mixed-oxide (uranium and plutonium) fuel as part of the commercial spent nuclear fuel inventory and that has been immobilized and included as part of the high-level

MATERIALS EVALUATED IN THIS EIS

Spent nuclear fuel is fuel that has been withdrawn from a reactor following irradiation.

- **Commercial** – from civilian nuclear powerplants that generate electricity (including mixed-oxide fuel)
- **DOE** – from DOE production reactors, naval reactors, test and experimental reactors, and research reactors (including some non-DOE reactors)

High-level radioactive waste is primarily waste that resulted from the chemical extraction of weapons-usable materials from the spent nuclear fuel. (Immobilized surplus weapons-usable plutonium is part of the high-level radioactive waste inventory.)

Greater-Than-Class-C waste is low level radioactive waste generated by commercial nuclear reactors that does not meet shallow land burial disposal limits.

Special-Performance-Assessment-Required waste is low-level radioactive wastes generated in DOE, production reactions, research reactions, reprocessing facilities, and research and development activities that exceed the Nuclear Regulatory Commission Class C shallow-land burial disposal limits.

Legend

- ★ Commercial sites

  Note: The EIS analysis considered three commercial site pairs — Salem and Hope Creek, Nine Mile Point and FitzPatrick, and Dresden and Morris — to be single sites due to their proximity to each other.

- ◉ DOE sites

  Note: The EIS analysis included the high-level radioactive waste and spent nuclear fuel at West Valley. The State of New Yorkowns the high-level radioactive waste and the site. Under the West Valley Demonstration Project Act, DOE is responsible for solidifying and transporting the high-level radioactive waste off the West Valley site. DOE owns and is responsible for the spent nuclear fuel at the site.

Figure S-1. Locations of commercial and DOE sites and Yucca Mountain.

radioactive waste inventory. Mixed-oxide fuel is a mixture of uranium oxide and plutonium oxide fuel that could be used to power commercial nuclear reactors.

When the DOE production reactors were operating, they used a controlled fission process to irradiate nuclear fuel and produce materials for nuclear weapons. After the spent nuclear fuel was removed from the reactors, chemical processes extracted the weapons-usable materials from the spent nuclear fuel. This is called reprocessing. The byproduct remaining after reprocessing is *high-level radioactive waste*. High-level radioactive waste also resulted from the reprocessing of naval reactor fuels and some commercial reactor fuels, some DOE test reactor fuels, and some non-DOE research reactor fuels.

In addition to spent nuclear fuel and high-level radioactive waste, DOE is responsible for the disposal of other waste types, referred to as *Greater-Than-Class-C* and *Special-Performance-Assessment-Required* wastes. These waste types are low-level radioactive wastes that have high radionuclide concentrations. They could become eligible for disposal in a geologic repository in the future, so DOE has analyzed the cumulative environmental impacts associated with the potential disposal of these wastes in a repository at Yucca Mountain.

S.2.2.1 Legislative History

Methods to dispose of radioactive wastes have been studied since the late 1950s. In 1980, President Carter declared that the safe disposal of radioactive waste generated by both defense and civilian nuclear activities is a national responsibility. In the *Environmental Impact Statement, Management of Commercially Generated Radioactive Waste* (DOE/EIS-0046, 1980), DOE analyzed the environmental impacts that could occur if it implemented alternative strategies for the management and disposal of spent nuclear fuel. The disposal alternatives included mined geologic disposal, very deep hole waste disposal, disposal in a mined cavity that results in rock melting, island-based geologic disposal, subseabed disposal, ice sheet disposal, well injection disposal, transmutation, space disposal (for example, launching waste into orbit around the sun), and no action. The Record of Decision for that EIS, issued in 1981, announced the DOE decision to pursue the mined geologic disposal alternative.

In 1982, Congress enacted the Nuclear Waste Policy Act in recognition of the need to provide for the permanent disposal of spent nuclear fuel and high-level radioactive waste in the United States. This Act established the Federal Government's responsibility to provide permanent disposal of the Nation's spent nuclear fuel and high-level radioactive waste and set forth a process and schedule for the disposal of these materials in a geologic repository. In 1986, following the process outlined in the original Nuclear Waste Policy Act, DOE narrowed the number of potentially acceptable sites for a geologic repository to three: Deaf Smith County in Texas; the Hanford Site in Washington; and Yucca Mountain. President Reagan approved the DOE recommendation of these sites as suitable for site characterization. In 1987, Congress amended the Nuclear Waste Policy Act and directed the Secretary of Energy to characterize only Yucca Mountain as a potential location for a geologic repository, setting forth a process for the Federal Government to decide whether to designate Yucca Mountain as the site for a repository.

SITE CHARACTERIZATION OF YUCCA MOUNTAIN

DOE has an ongoing program of investigations and evaluations to assess the characteristics of Yucca Mountain as a potential monitored geologic repository and to provide information for this environmental impact statement. Data from site characterization activities have been used to describe the existing environment at the Yucca Mountain site and to assess the potential impacts of the proposed repository.

The site characterization program consists of scientific, engineering, and technical studies and activities. Site investigations and evaluations include the construction of the Exploratory Studies Facility, which is a large underground laboratory consisting of a long tunnel or *main drift* and side tunnels and rooms inside the mountain; investigations of the hydrology

and geology of the site; studies of socioeconomics, cultural resources, and terrestrial ecosystems; and monitoring of air quality, meteorological, radiological, and water resource data.

S.2.2.2 Future Activities and Decisions

Decision Process for Site Recommendation. Under the NWPA, DOE is required to hold hearings in the vicinity of Yucca Mountain to provide the public with opportunities to comment on the Secretary's possible recommendation of the site to the President. If, after completing the hearings and site characterization activities, the Secretary decides to recommend that the President approve Yucca Mountain, the Secretary will notify the Governor and legislature of the State of Nevada accordingly. No sooner than 30 days after the notification, the Secretary may submit the recommendation to the President to approve the site for development of a repository. The NWPA further requires that the Secretary's recommendation to the President be based on the record of information developed through the site characterization program, as well as other sources, including the Final EIS.

DOE general guidelines (10 CFR Part 960) for assessing the suitability of multiple repository sites consider the location of valuable natural resources, hydrology, geophysics, seismic activity, atomic energy defense activities, and proximity to water supplies, populations, and public lands such as national parks and forests. In 1996, the Department proposed to amend the general guidelines to describe the process and criteria for evaluating the suitability of only the Yucca Mountain site, in accordance with the NWPA, but did not finalize that proposal. DOE has not yet made a decision whether to amend the current guidelines. As required by the NWPA, if the Secretary recommends the site, DOE will consider guidelines that are applicable at that time.

Decision Process for U.S. Nuclear Regulatory Commission Licensing. If the President and Congress approve the site, DOE will submit a License Application to the Nuclear Regulatory Commission for authorization to construct a geologic repository. The NWPA directs the Commission to adopt the Final EIS to the extent practicable in its decision on whether to issue a construction authorization and license for such a repository.

The Nuclear Regulatory Commission has issued requirements governing its licensing of DOE to construct a geologic repository and to receive and possess nuclear material at that repository (10 CFR Part 60). The Commission has stated its intention to amend these requirements as necessary to be consistent with standards that the U.S. Environmental Protection Agency is expected to promulgate for the storage and disposal of spent nuclear fuel and high-level radioactive waste at the Yucca Mountain site (40 CFR Part 197). Figure S-2 shows the sequence of past disposal decisions and projected activities.

REGULATORY STANDARDS

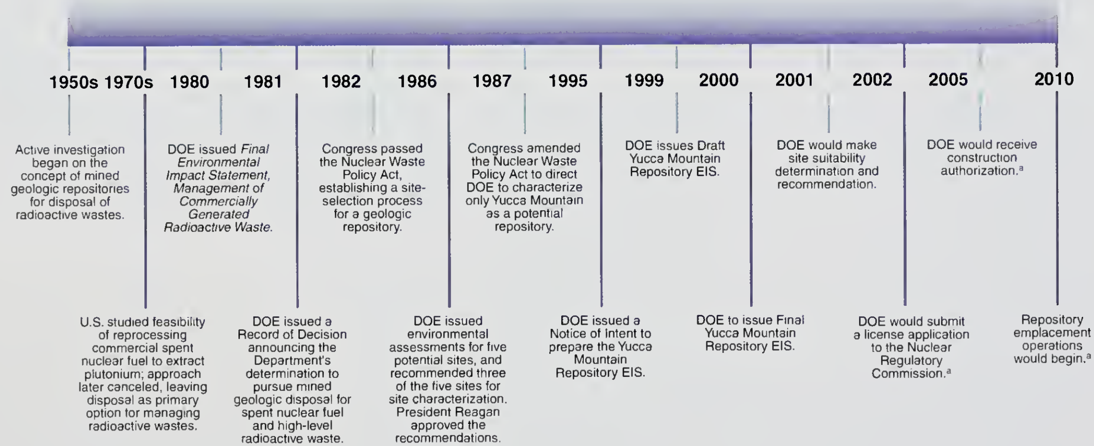
10 CFR Part 60: Nuclear Regulatory Commission regulations on the Disposal of High-Level Radioactive Waste in Geologic Repositories.

10 CFR Part 63 (Proposed February 22, 1999): Nuclear Regulatory Commission site-specific technical requirements are criteria to be used to approve or disapprove an application to construct a repository at Yucca Mountain, to receive and possess spent nuclear fuel and high-level radioactive waste at such a repository, and to close and decommission such a repository.

40 CFR Part 197 (in preparation): Environmental Protection Agency standards on the Storage and Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste.

S.2.2.3 Issues Raised in Public Scoping

DOE solicited written comments and held 15 public scoping meetings across the country between August 29 and October 24, 1995, to enable interested parties to present comments



a. If Yucca Mountain is approved.

Figure S-2. Sequence of past disposal decisions and possible future repository activities.

on the scope of this EIS. During the public scoping process, a number of commenters asked that the EIS discuss the history of the Yucca Mountain site characterization program and requirements of the NWPA, address DOE's responsibility to begin accepting waste in 1998, describe the potential decisions that the EIS would support, and examine activities other than construction, operation and monitoring, and closure of a repository at Yucca Mountain. Other comments raised during public scoping addressed the consistency of the proposed repository with existing land uses, effects of earthquakes and volcanism, health and safety impacts, long-term impacts, and sabotage. In response to the public's input, DOE included discussions and analysis of these issues in the EIS.

DOE also received comments noting that the nation will have more than 70,000 metric tons of heavy metal (MTHM) of spent nuclear fuel and high-level radioactive waste, although the NWPA directs that the maximum amount allowed for repository disposal is 70,000 MTHM of these materials until a second repository is in operation. Commenters encouraged DOE to evaluate the disposal of the entire anticipated inventory of spent nuclear fuel and high-level radioactive waste and other waste types that might also require permanent isolation. For this reason, the EIS analyzes cumulative environmental impacts that could occur from the disposal at Yucca Mountain of the country's total projected inventory of spent nuclear fuel and high-level radioactive waste, as well as Greater-Than-Class C and Special Performance Assessment Required waste. In response to other public scoping comments, DOE added an additional transportation corridor and route in Nevada to the analysis.

DEFINITION OF METRIC TONS OF HEAVY METAL

Quantities of spent nuclear fuel are traditionally expressed in terms of *metric tons of heavy metal* (typically uranium), without the inclusion of other materials such as cladding (the tubes containing the fuel) and structural materials. A metric ton is 1,000 kilograms (1.1 tons or 2,200 pounds). Uranium and other metals in spent nuclear fuel (such as thorium and plutonium) are called *heavy metals* because they are extremely dense; that is, they have high weights per unit volume. One metric ton of heavy metal disposed of as spent nuclear fuel would fill a space approximately the size of a typical household refrigerator.

Many other public scoping comments presented views and concerns not related to the scope or content of the Proposed Action. Examples of these comments include statements in general support of or opposition to a repository at Yucca Mountain, geologic repositories in general, and nuclear power; lack of public confidence in the Yucca Mountain program; perceived inequities and political aspects of the siting process by which Congress selected Yucca Mountain for further study; the constitutional basis for waste disposal in Nevada; perceived psychological costs or effects; risk perception and stigmatization; legal issues involving Native American land claims and treaty rights; and unrelated DOE activities. DOE considered and recorded these concerns, but has not included analyses of these issues in the EIS.

S.3 Proposed Action and No-Action Alternative

S.3.1 PROPOSED ACTION

Under the Proposed Action, DOE would construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The Proposed Action would include the transportation of spent nuclear fuel and high-level radioactive waste from commercial and DOE sites to the Yucca Mountain site.

DOE would dispose of spent nuclear fuel and high-level radioactive waste in the repository using the natural geologic features of the mountain and engineered barriers as a total system to ensure the long-term isolation of the materials from the accessible environment. DOE would build the repository inside Yucca Mountain between 200 meters and 425 meters (660 and 1,400 feet) below the surface and between 175

PREFERRED ALTERNATIVE

DOE's preferred alternative is to proceed with the Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The analyses in this EIS did not identify any potential environmental impacts that would be a basis for not proceeding with the Proposed Action. DOE has not chosen any mode, corridor, or route as preferred at this time. It has, however, designated the Caliente-Chalk Mountain rail corridor and heavy-haul route as "nonpreferred alternatives."

and 365 meters (570 and 1,200 feet) above the water table. Figure S-3 shows the location of the proposed repository at Yucca Mountain.

In addition, the Proposed Action would include the use of active institutional controls (controlled access, inspection, and maintenance, etc.) through the end of the closure period, and the use of passive institutional controls (markers, engineered barriers, etc.) after the completion of closure. The purpose of the passive institutional controls would be to prevent inadvertent intrusion by and exposures to members of the public.

S.3.1.1 Repository and Waste Package Design

The repository would be a large underground excavation with a number of interconnecting tunnels (called drifts) that DOE would use for waste emplacement. Figure S-4 shows the proposed repository concept.

DOE would receive materials at the repository in one of three configurations: uncanistered fuel (spent nuclear fuel placed directly in a shipping cask), dual-purpose canisters (containment vessel structures designed to store and transport commercial spent nuclear fuel), or disposable canisters (canisters for spent nuclear fuel or high-level radioactive waste with multiple specialized overpacks to enable their storage, transportation, and emplacement in a repository). DOE cannot establish the particular combination of uncanistered fuel, dual-purpose canisters, or disposable canisters it would receive at a repository because the commercial and DOE sites will determine the canister type they will use. For that reason, the Department analyzed two scenarios [uncanistered and canistered (including dual-purpose canisters and disposable canisters)] that cover the possible range of repository and transportation impacts to human health and the environment.

NATURAL AND ENGINEERED FEATURES

Water is the primary means by which radionuclides disposed of at Yucca Mountain could reach the accessible environment. The natural features of the very dry climate, large distance to the water table, and geology of the site would act to limit the amount of water that entered the repository. The engineered features, including waste packages made from corrosion-resistant material, would deter releases of radioactive material, even in the presence of any water that reached the emplacement area.

Material received at the repository would be unloaded from the shipping casks and placed in disposal containers that would then be sealed. The sealed disposal containers are called *waste packages*. Remote-controlled handling vehicles would place the waste packages in emplacement drifts.

According to the Viability Assessment reference design (that is, the repository design used for purposes of analysis in this EIS), the waste packages would have two layers: a structurally strong outer layer of carbon steel about 10 centimeters (4 inches) thick, and a corrosion-resistant inner layer of high-nickel alloy (Alloy-22) about 2 centimeters (0.8 inch) thick. These two layers would work together to help

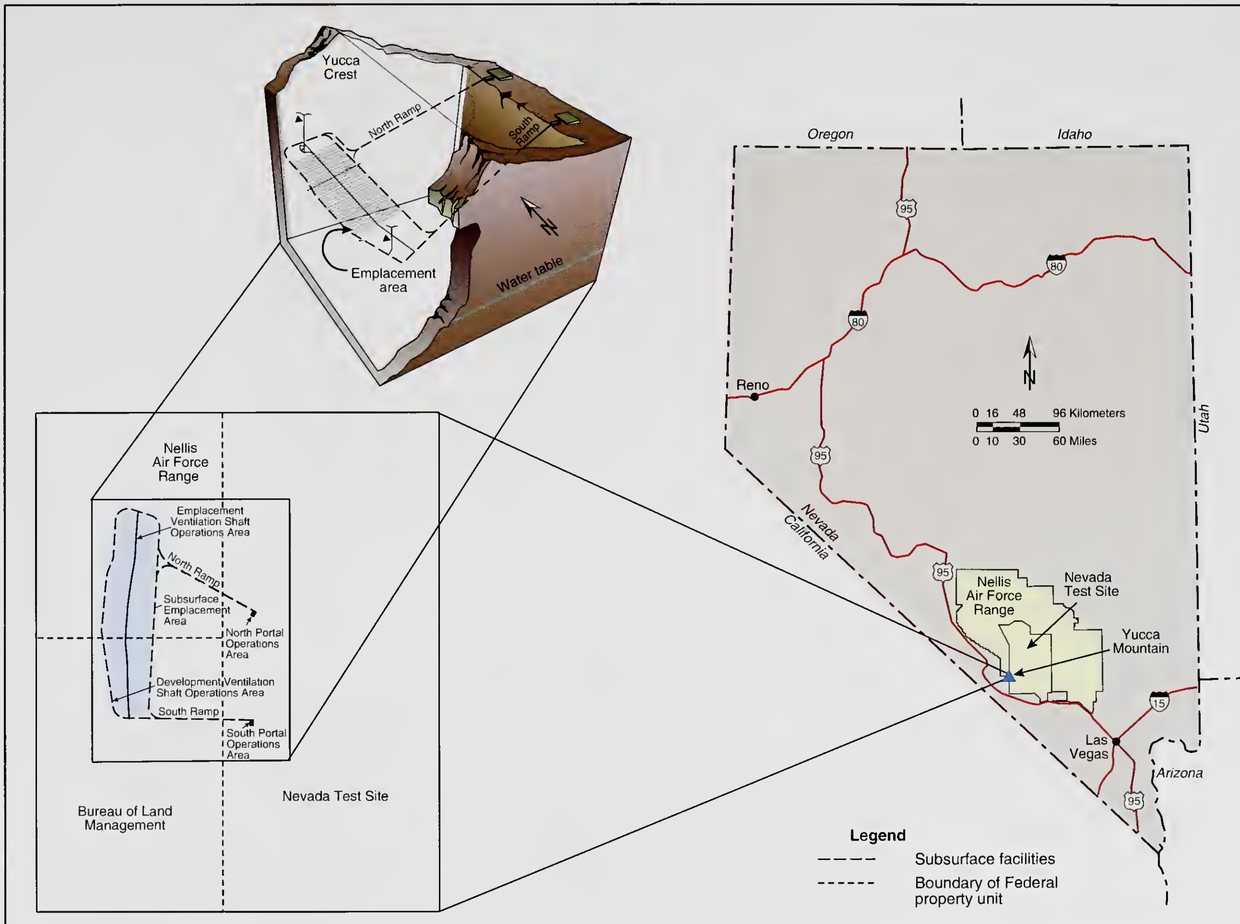


Figure S-3. Location of the proposed repository at Yucca Mountain.

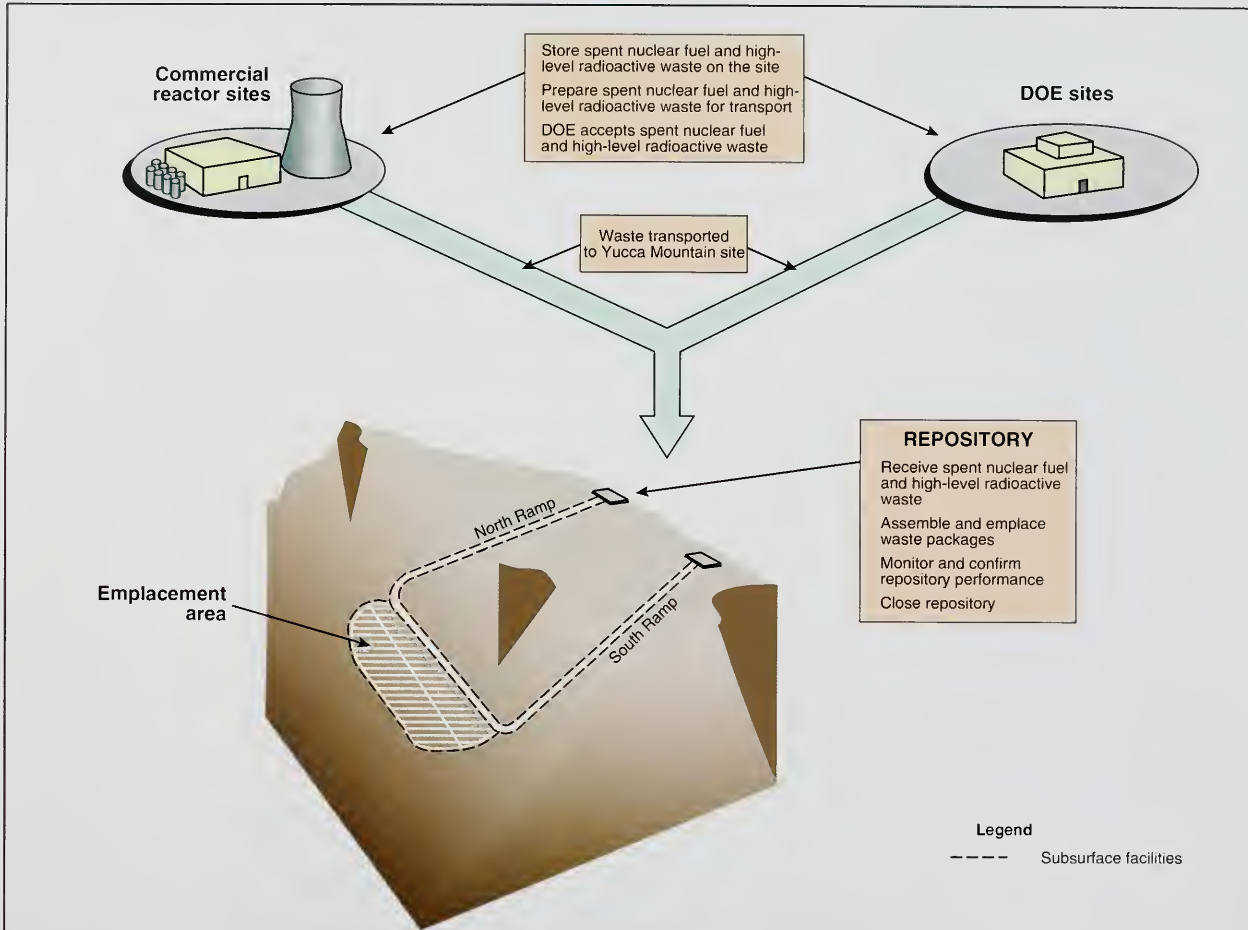


Figure S-4. Spent nuclear fuel and high-level radioactive waste handling, transportation, and disposal.

DEFINITIONS OF PACKAGING TERMS

Shipping cask: A thick-walled vessel that meets applicable regulatory requirements for shipping spent nuclear fuel or high-level radioactive waste.

Canister: A thin-walled metal vessel used to hold spent nuclear fuel assemblies or solidified high-level radioactive waste.

Dual-purpose canister: A canister suitable for storing (in a storage facility) and shipping (in a shipping cask) spent nuclear fuel assemblies. At the repository, dual-purpose canisters would be removed from the shipping cask and opened. The spent nuclear fuel assemblies would be removed from the canister and placed in a disposal container. The opened canister would be recycled or disposed of offsite as low-level radioactive waste.

Disposable canister: A canister for spent nuclear fuel assemblies or solidified high-level radioactive waste suitable for storage, shipping, and disposal. At the repository, the disposable canister would be removed from the shipping cask and placed directly in a disposal container.

Uncanistered spent nuclear fuel: Fuel placed directly into storage canisters or shipping casks without first being placed in a canister. At the repository, spent nuclear fuel assemblies would be removed from the shipping cask and placed in a disposal container.

Disposal container: A container for spent nuclear fuel and high-level radioactive waste consisting of the barrier materials and internal components. The filled, sealed, and tested disposal container is referred to as the *waste package*, which would be emplaced in the repository.

Waste package: The filled, sealed, and tested disposal container that would be emplaced in the repository.

preserve the integrity of the waste package for thousands of years. The waste packages would be the primary part of an engineered barrier system in the mountain. This system would, in combination with the natural features of the site, help retard the release of radioactive material to the accessible environment for long periods.

Under the Proposed Action, DOE would emplace 10,000 to 11,000 waste packages containing no more than 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in the repository. Of that amount, 63,000 MTHM would be spent nuclear fuel assemblies that would be shipped from commercial sites to the repository. The remaining 7,000 MTHM would consist of about 2,333 MTHM of DOE spent nuclear fuel and high-level radioactive waste currently estimated to be approximately 8,315 canisters (the equivalent of 4,667 MTHM) that DOE would ship to the repository from DOE sites.

To determine the number of canisters of high-level radioactive waste included in the Proposed Action waste inventory, DOE used 0.5 MTHM per canister of defense high-level radioactive waste. DOE has used the 0.5-MTHM-per-canister approach since 1985. Using a different approach would change the number of canisters of high-level radioactive waste in the Proposed Action. Regardless of the number of canisters, the impacts of the analysis would not significantly change because long-term repository performance results are determined by the spent nuclear fuel inventory. In addition, the EIS analyzes the impacts from the entire inventory of high-level radioactive waste in the cumulative impacts analysis.

The inventory includes approximately 50 MTHM of surplus weapons-usable plutonium. At present, DOE expects that approximately 32 MTHM of the plutonium would be converted into mixed-oxide fuel, which

is included as part of the commercial spent nuclear fuel inventory. DOE expects the remaining approximately 18 MTHM of plutonium to be immobilized and included in the high-level radioactive waste inventory.

Figure S-5 shows potential waste package designs for spent nuclear fuel and high-level radioactive waste. Figure S-6 shows waste packages in an emplacement drift.

S.3.1.2 Performance Confirmation, Construction, Operation and Monitoring, and Closure

DOE would construct and operate surface facilities at the repository site to receive, prepare, and package spent nuclear fuel and high-level radioactive waste for emplacement in underground drifts. The surface and subsurface facilities developed for site characterization activities at Yucca Mountain would be incorporated into the repository design to the extent practicable. Figures S-7 and S-8 show conceptual designs of the surface and subsurface facilities, respectively. Figure S-9 shows the sequence for repository development at Yucca Mountain.

THERMAL LOAD

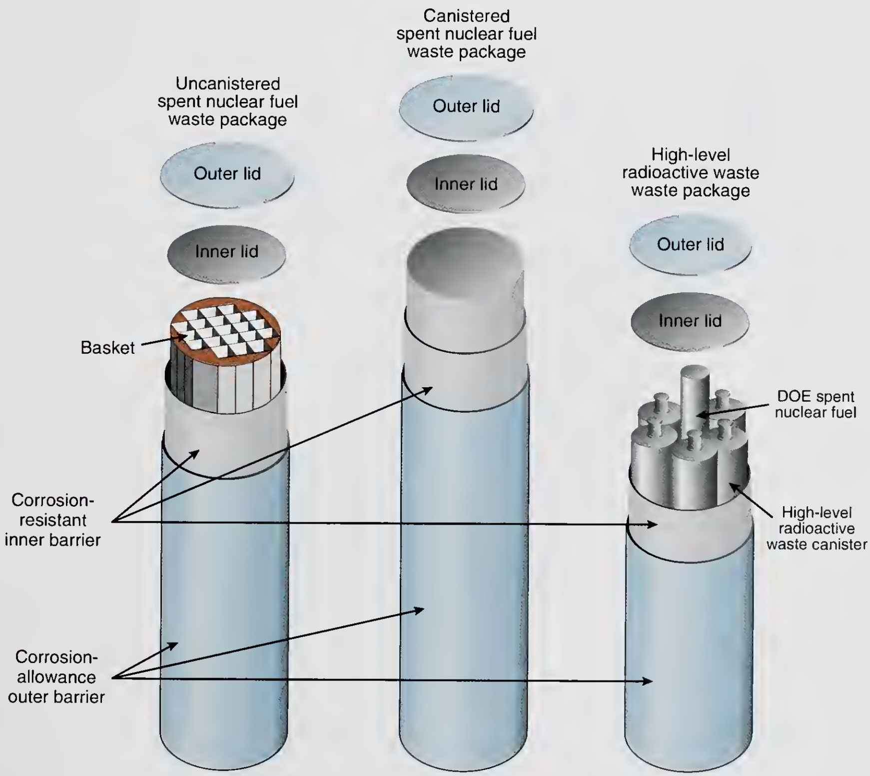
The heat generated by spent nuclear fuel and high-level radioactive waste in the waste packages creates a *thermal load*, which could affect the long-term performance of the repository (that is, the ability of the engineered and natural barrier systems to isolate the emplaced waste from the environment). Thermal load also could affect short-term repository attributes including the amount of surface area required for construction and operations, the number of workers, and utility consumption. Most of the thermal load is from commercial spent nuclear fuel.

DOE evaluated three thermal load scenarios to consider a range of the short- and long-term environmental impacts from repository construction, operation and monitoring, and closure. These scenarios include the *high thermal load*, a relatively high emplacement density of commercial spent nuclear fuel (85 MTHM per acre); the *low thermal load*, a relatively low density (25 MTHM per acre); and the *intermediate thermal load* between the high and low thermal loads (60 MTHM per acre). The spacing of the emplacement drifts and the spacing of the waste packages in the drifts are two examples of techniques that could control the thermal load. The additional spacing for the lower thermal loads would increase the subsurface area and the amount of excavation. In addition, the different thermal loads would affect the area requirements for the excavated rock pile on the surface.

Performance confirmation. Performance confirmation activities would be similar to the current site characterization activities and would include tests, experiments, and analyses that DOE would conduct to evaluate the long-term performance of the repository. Before the start of repository construction, the performance confirmation program would assume responsibility for activities now being performed as part of site characterization. Those activities would continue until after the closure of the repository.

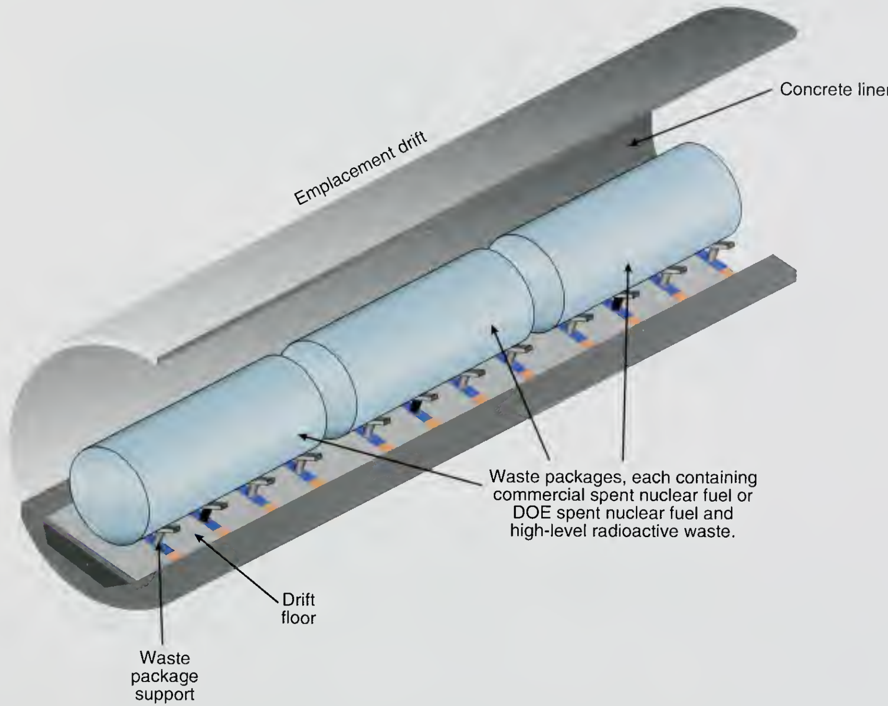
Construction. The construction of repository surface and subsurface facilities could begin after the receipt of construction authorization from the Nuclear Regulatory Commission. For analytical purposes, DOE assumed that construction would begin in 2005. The Department would build the repository surface facilities, main drifts, ventilation system, and initial emplacement drifts in about 5 years, from 2005 to 2010. Construction of the emplacement drifts would continue after emplacement began.

Surface facilities would receive, prepare, and package spent nuclear fuel and high-level radioactive waste for emplacement, and would support the construction of subsurface facilities. The primary surface facilities would be the *North Portal Operations Area* (including the *Waste Handling Building*), the *South Portal Operations Area* (supporting subsurface facility development), the *Emplacement Ventilation Shaft Surface Operations Area(s)*, and the *Development Ventilation Shaft Operations Area(s)*.



Note: Waste packages would range in size from 3.7 to 6.2 meters (12 to 20 feet) long and 1.25 to 2.0 meters (4.1 to 6.6 feet) in diameter. They would range in weight from 35,000 kilograms (77,000 pounds) to 83,000 kilograms (183,000 pounds).

Figure S-5. Potential waste package designs for spent nuclear fuel and high-level radioactive waste.



Note: Spacing between packages is for illustration only. The actual spacing would be determined as a function of the final repository thermal load design.

Figure S-6. Artist's conception of waste packages in emplacement drift.

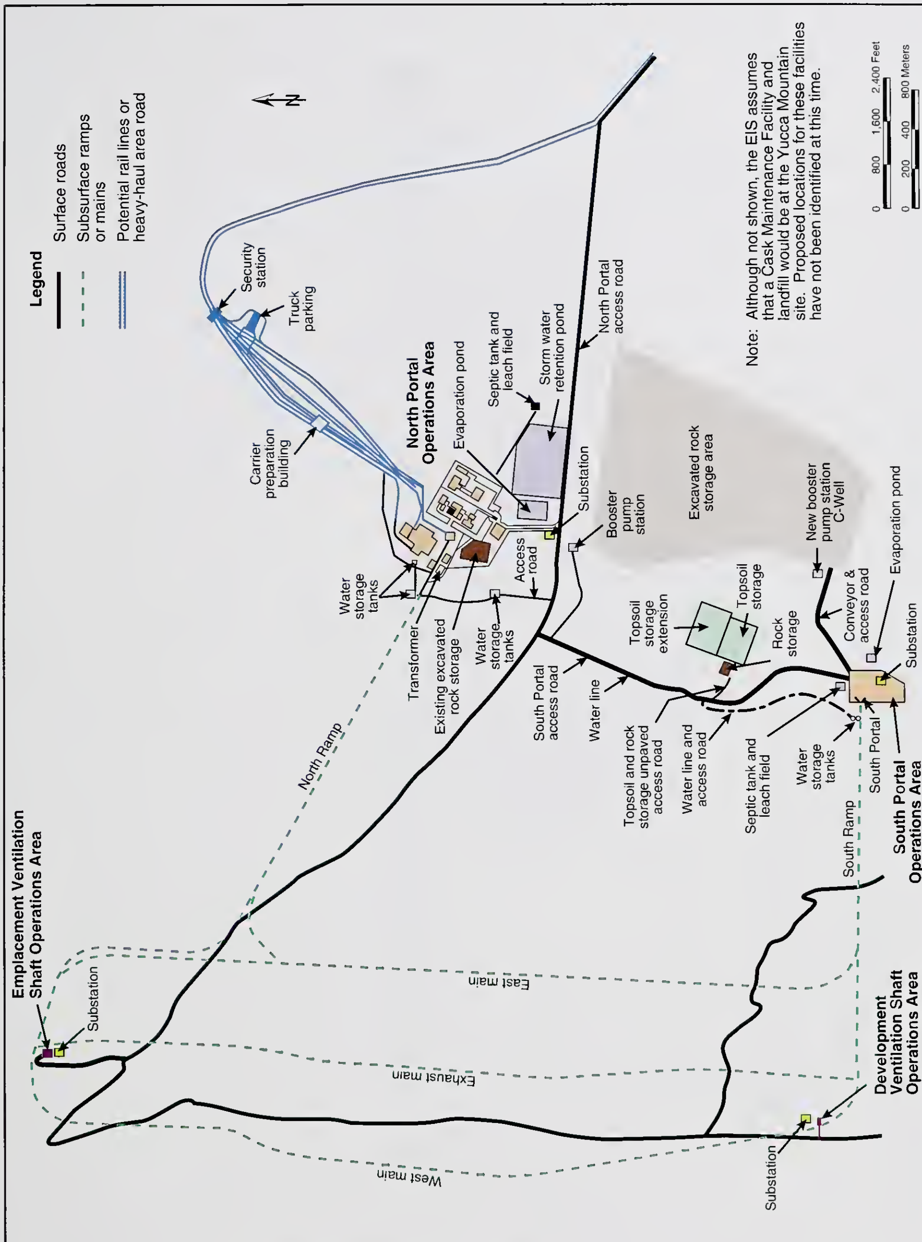


Figure S-7. Repository surface facilities plan.

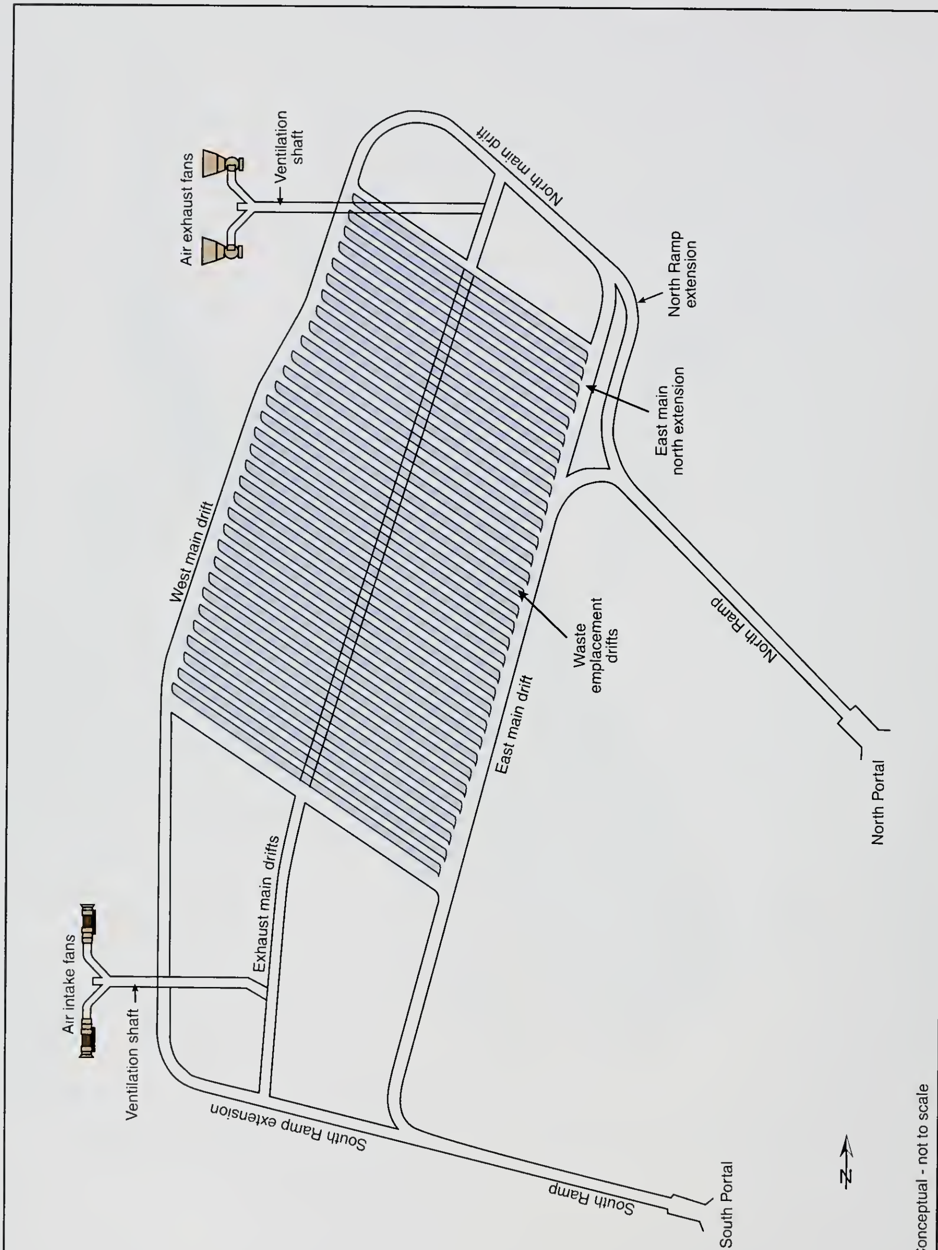
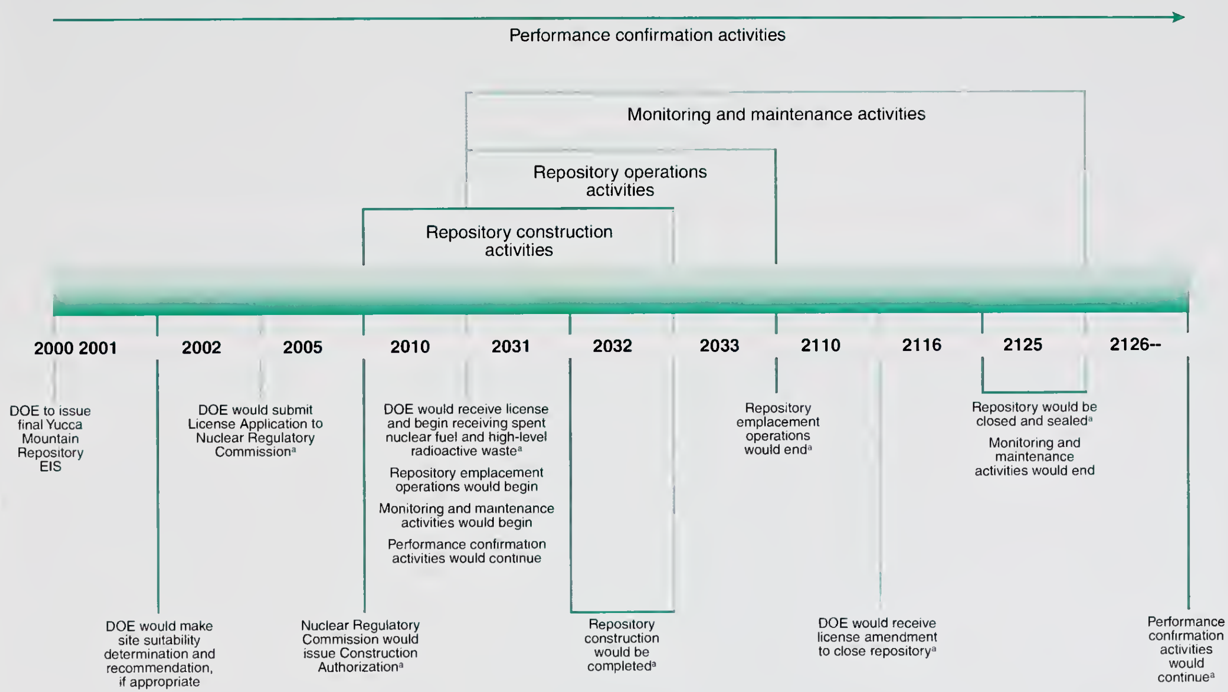


Figure S-8. Repository subsurface facilities plan.



a. If Yucca Mountain is approved.

Figure S-9. Expected sequence for proposed Yucca Mountain Repository development.

EVOLVING REPOSITORY DESIGN

The EIS analyzes thermal load and packaging scenarios to identify the range of potential short- and long-term impacts of a repository at Yucca Mountain. The analysis used conceptual designs, which is typical for an EIS. However, the current level of repository design is insufficient to meet information needs for a License Application to the Nuclear Regulatory Commission. The design will continue to evolve through the submittal of the License Application. The DOE License Application Design Selection process is evaluating various features and enhanced design alternatives. The purpose of the evaluation is to determine if these features and alternatives would reduce uncertainties in or improve the long-term performance of the repository, reduce costs, or improve operations.

The reference design discussed in the EIS, together with the thermal load and packaging scenarios, are representative of the design features and enhanced design alternatives under evaluation.

Subsurface facilities would include the drifts developed during site characterization activities. During construction, additional underground excavation would occur. Excavation in the subsurface facilities would include gently sloping *access ramps* for the movement of construction and waste package vehicles, *main drifts* for the movement of construction and waste package vehicles, *emplacement drifts* for the placement of waste packages, *exhaust mains* to transfer air in the subsurface area, and *ventilation shafts* to transfer air between the surface and the subsurface. *Performance confirmation drifts* would contain instrumentation to monitor emplaced waste packages.

Operation and Monitoring. Repository operations would begin after the Nuclear Regulatory Commission granted a license to "receive and possess" spent nuclear fuel and high-level radioactive waste. For planning purposes, DOE assumed that the receipt and emplacement of these materials would begin in 2010. Based on a total emplacement of 70,000 MTHM at approximately 3,000 MTHM each year, waste emplacement would end in about 2033.

The construction of emplacement drifts would continue during the waste emplacement period, and would end in about 2031 for the high or intermediate thermal load scenario or 2032 for the low thermal load scenario. The repository design would enable simultaneous construction and emplacement operations, but it would physically separate construction or development activities from emplacement activities. Ventilation barriers would create airlocks to separate the emplacement and development sides of the repository, and the ventilation system would be designed to maintain the emplacement side at a lower pressure than the development side. This would ensure that no air leakage would occur from the emplacement side to the development side.

Monitoring and maintenance activities would begin with the first emplacement of waste packages and would continue until repository closure. After the completion of emplacement, DOE would maintain the repository facilities, including the ventilation system and utilities (air, water, electric power) that would enable the continued monitoring and inspection of waste packages, continued investigations of long-term repository performance, and the retrieval of waste packages, if necessary. Immediately after the completion of emplacement, DOE would decontaminate and close the nuclear facilities on the surface to eliminate potential radioactive material

RETRIEVAL

Section 122 of the NWPA requires DOE to maintain the ability to retrieve emplaced materials. Because of this requirement, the EIS includes an analysis of the impacts of retrieval. Although the EIS analyzes it, DOE does not believe that retrieval would be necessary, and it is not part of the Proposed Action. DOE would maintain the ability to retrieve the spent nuclear fuel and high-level radioactive waste for at least 100 years and possibly for as long as 300 years in the event of a decision to retrieve the materials to protect public health and safety or the environment or to recover constituent parts of spent nuclear fuel.

hazards. However, the Department would maintain the Waste Handling Building for the possible retrieval of waste.

Closure. To ensure flexibility for future decisionmakers, DOE is designing the repository with a capability for closure in as few as 50 years or as many as 300 years after the start of waste emplacement. While the reference design assumes that closure would begin 100 years after emplacement began, this EIS assessed impacts for closure beginning 50 and 300 years after the start of emplacement.

Repository closure would occur after DOE received a license amendment from the Nuclear Regulatory Commission. The period to perform closure would range from 6 years to 15 years, depending on the thermal load (a longer period would be needed to close the larger number of drifts needed for the low thermal load). Closure activities would include closing the subsurface facilities, decommissioning the surface facilities, sealing openings into the mountain (access ramps, ventilation shafts, boreholes), performing reclamation activities at the site, and establishing institutional controls such as permanent monuments to mark and identify the area.

S.3.1.3 Transportation

DOE would transport spent nuclear fuel and high-level radioactive waste from commercial and DOE sites around the country to the Yucca Mountain site by rail and legal-weight truck. The Department is not proposing to use a particular combination of rail and legal-weight truck shipments, so it analyzed two transportation scenarios (*mostly legal-weight truck* and *mostly rail*) that cover the possible range of transportation impacts to human health and the environment.

DEFINITIONS FOR TRUCK TRANSPORTATION

Legal-weight trucks: trucks with a gross vehicle weight (both truck and cargo weight) of less than 36,300 kilograms (80,000 pounds), which is the loaded weight limit for commercial vehicles operated on public highways without special state-issued permits.

Heavy-haul trucks: overweight, overdimension vehicles that must have permits from state highway authorities to use public highways.

The mostly legal-weight truck scenario assumes that DOE would transport most of the spent nuclear fuel and high-level radioactive waste to the repository by legal-weight truck. The trucks would travel from the 77 sites to the Yucca Mountain site primarily on the U.S. Interstate Highway system, as shown in Figure S-10. An exception to this scenario would be the naval spent nuclear fuel, which the Navy would transport from the Idaho National Engineering and Environmental Laboratory to Nevada by rail.

The mostly rail scenario assumes that DOE and the Navy would transport most of the spent nuclear fuel and high-level radioactive waste to Nevada by rail, with the exception of material from commercial nuclear generating sites that do not have the capability to load large-capacity rail shipping casks. Those sites would use legal-weight trucks to ship material to the repository. Commercial sites with the capability to load the rail shipping casks but that did not have rail access could use heavy-haul trucks or barges to ship spent nuclear fuel to the nearest rail line. Figure S-11 shows the commercial and DOE sites and Yucca Mountain in relation to the U.S. railroad system over which the railcars would travel.

NEVADA TRANSPORTATION IMPLEMENTING ALTERNATIVES

Rail corridors
- Caliente
- Caliente-Chalk Mountain
- Carlin
- Jean
- Valley Modified

Intermodal transfer station locations and heavy-haul truck routes
- Apex-Dry Lake (one route)
- Caliente
  - Caliente route
  - Caliente-Chalk Mountain route
  - Caliente-Las Vegas route
- Sloan/Jean (one route)

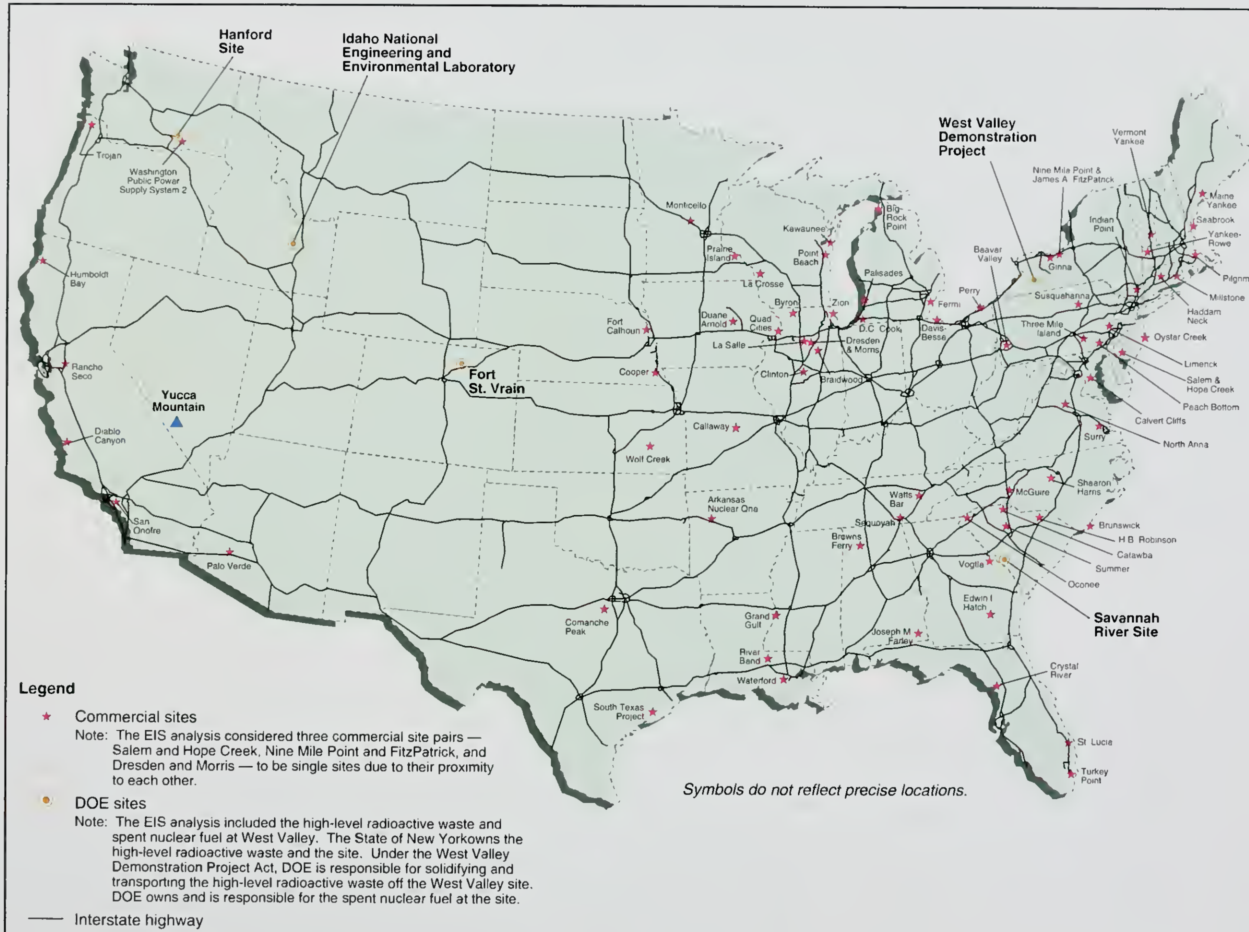


Figure S-10. Commercial and DOE sites and Yucca Mountain in relation to the U.S. Interstate Highway System.

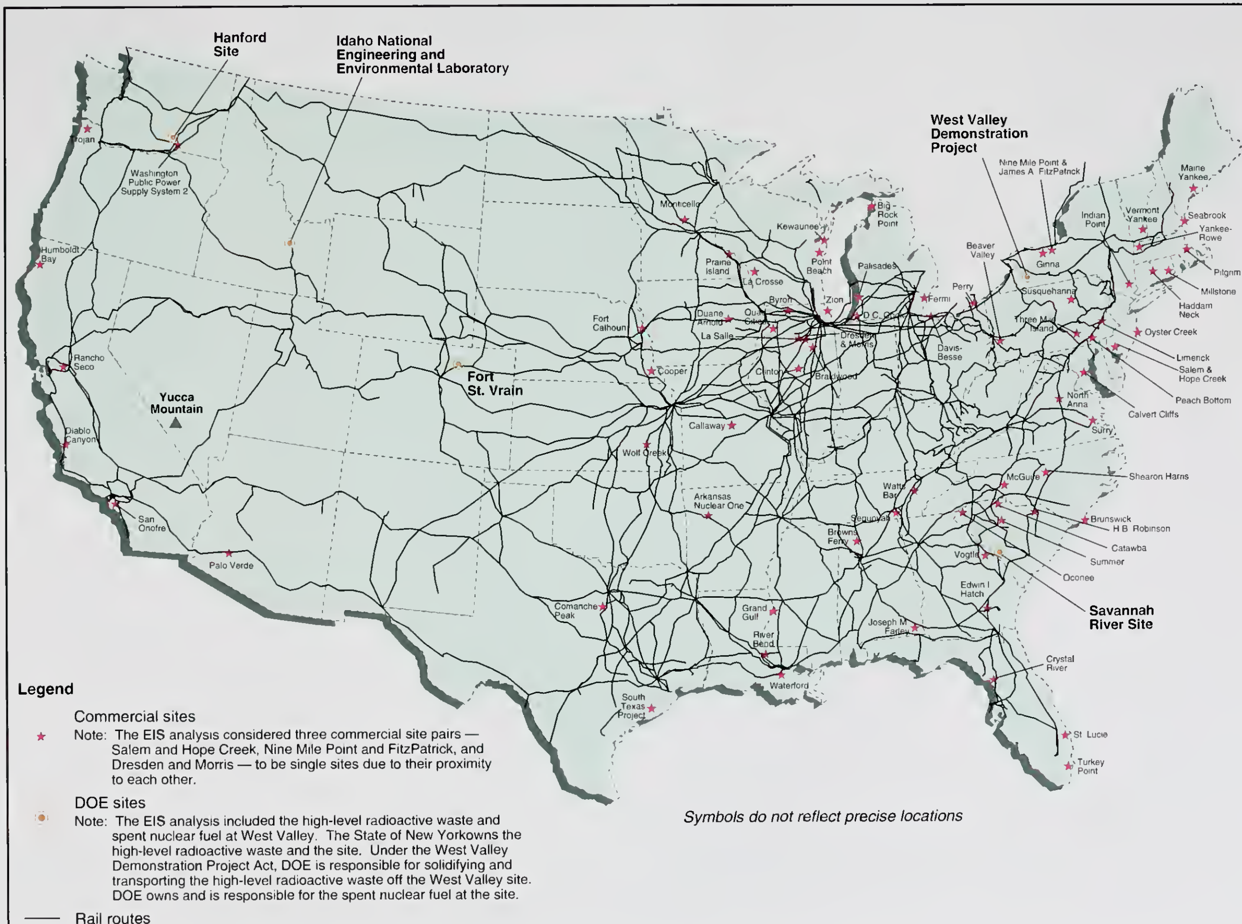


Figure S-11. Commercial and DOE sites and Yucca Mountain in relation to the U.S. railroad system.

In the State of Nevada, waste that traveled from the commercial and DOE sites by legal-weight truck would continue to the repository in the same manner. Figure S-12 shows the southern Nevada highways over which the legal-weight trucks would travel. Potential routes for legal-weight truck shipments in Nevada comply with U.S. Department of Transportation regulations (49 CFR 397.101) for selecting "preferred routes" and "delivery routes" for motor carrier shipments of highway route-controlled quantities of radioactive materials. The State of Nevada could designate alternative routes as specified in 49 CFR 397.103.

REPOSITORY ANALYSIS

Repository Facilities and Operations

Packaging scenarios
- Mostly uncanistered fuel
- Mostly canistered fuel

Thermal load scenarios
- High thermal load
- Intermediate thermal load
- Low thermal load

Transportation Activities

National transportation scenarios
- Mostly legal-weight truck
- Mostly rail

Nevada transportation scenarios
- Mostly legal-weight truck
- Mostly rail with a new branch rail line (five corridors)
- Mostly rail with heavy-haul truck from a new intermodal transfer station (five routes)

At this time there is no rail access to the Yucca Mountain site. This means that material traveling by rail would have to continue to the repository on a new branch rail line or transfer to heavy-haul trucks at an intermodal (that is, from rail to truck) transfer station in Nevada and then travel on existing highways that could need to be upgraded. DOE is considering implementing alternatives for the construction of either a new branch rail line or an intermodal transfer station with associated highway improvements. The Department has identified five alternatives for rail corridors, each of which has alignment variations (Figure S-13), and three alternative locations for an intermodal transfer station and five associated highway routes for heavy-haul trucks (Figure S-14). Figure S-15 shows how the national and Nevada transportation scenarios relate.

S.3.1.4 Costs

DOE estimates that the total cost of the Proposed Action (construct, operate and monitor for 100 years, and close a geologic repository at Yucca Mountain), including the transportation of spent nuclear fuel and high-level radioactive waste to the repository, would be about $28.8 billion (in 1998 dollars). This would vary, depending on the thermal load, packaging, other repository design features, and transportation scenarios, and on the Nevada transportation implementing alternative.

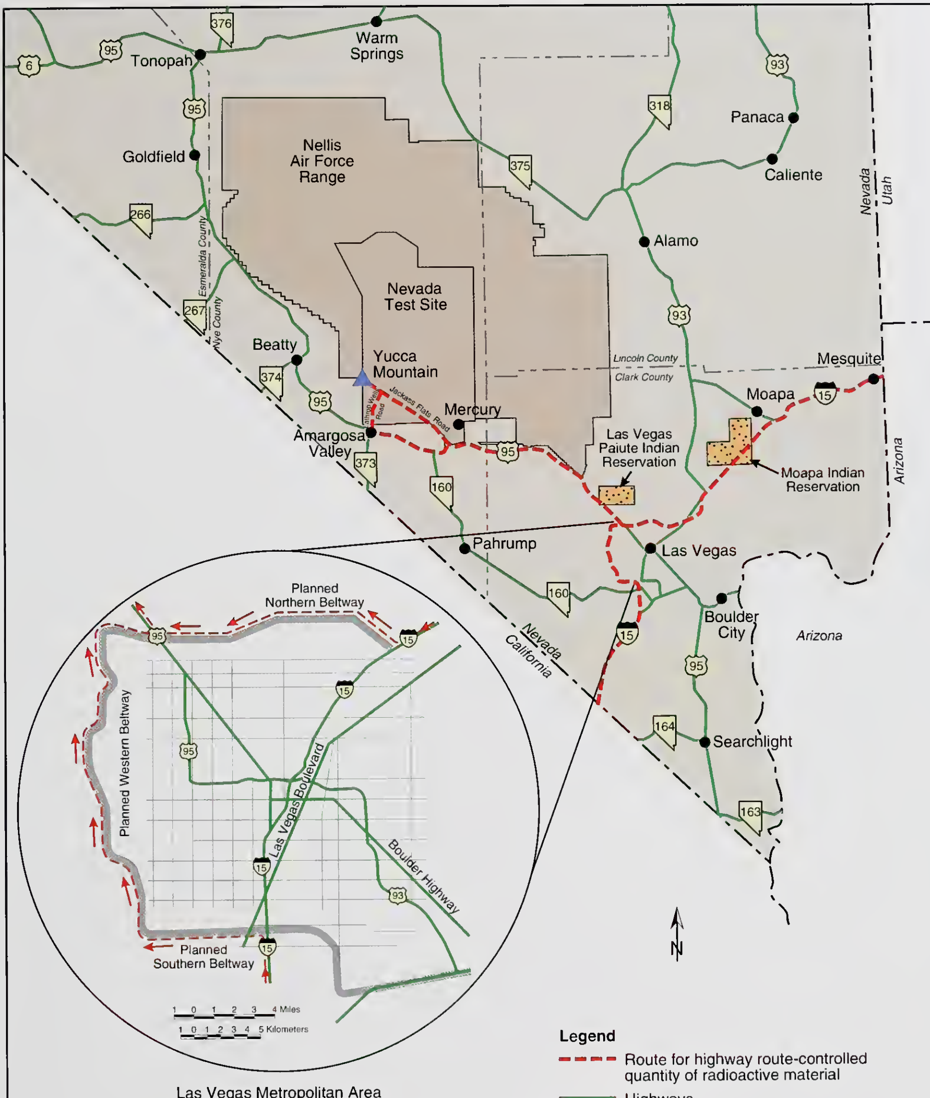
S.3.2 NO-ACTION ALTERNATIVE

Under the No-Action Alternative, DOE would end site characterization activities at Yucca Mountain and begin site decommissioning and reclamation. The commercial nuclear power utilities and DOE would continue to store spent nuclear fuel and high-level radioactive waste. Because it would be highly speculative to attempt to predict future events, DOE decided to illustrate one set of possibilities by focusing its analysis of the No-Action Alternative on the potential impacts of two scenarios:

- Scenario 1 assumes that spent nuclear fuel and high-level radioactive waste would remain at the 72 commercial and 5 DOE sites under institutional control for at least 10,000 years.

INSTITUTIONAL CONTROL

Monitoring and maintenance of storage facilities to ensure that radiological releases to the environment and radiation doses to workers and the public remain within Federal limits and DOE Order requirements.



Potential routes for legal-weight truck shipments in Nevada comply with U.S. Department of Transportation regulations (49 CFR 397.101) for selecting "preferred routes" and "delivery routes" for motor carrier shipments of highway route-controlled quantities of radioactive materials. The State of Nevada could designate alternative routes as specified in 49 CFR 397.103.

Figure S-12. Potential Nevada routes for legal-weight truck shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain.

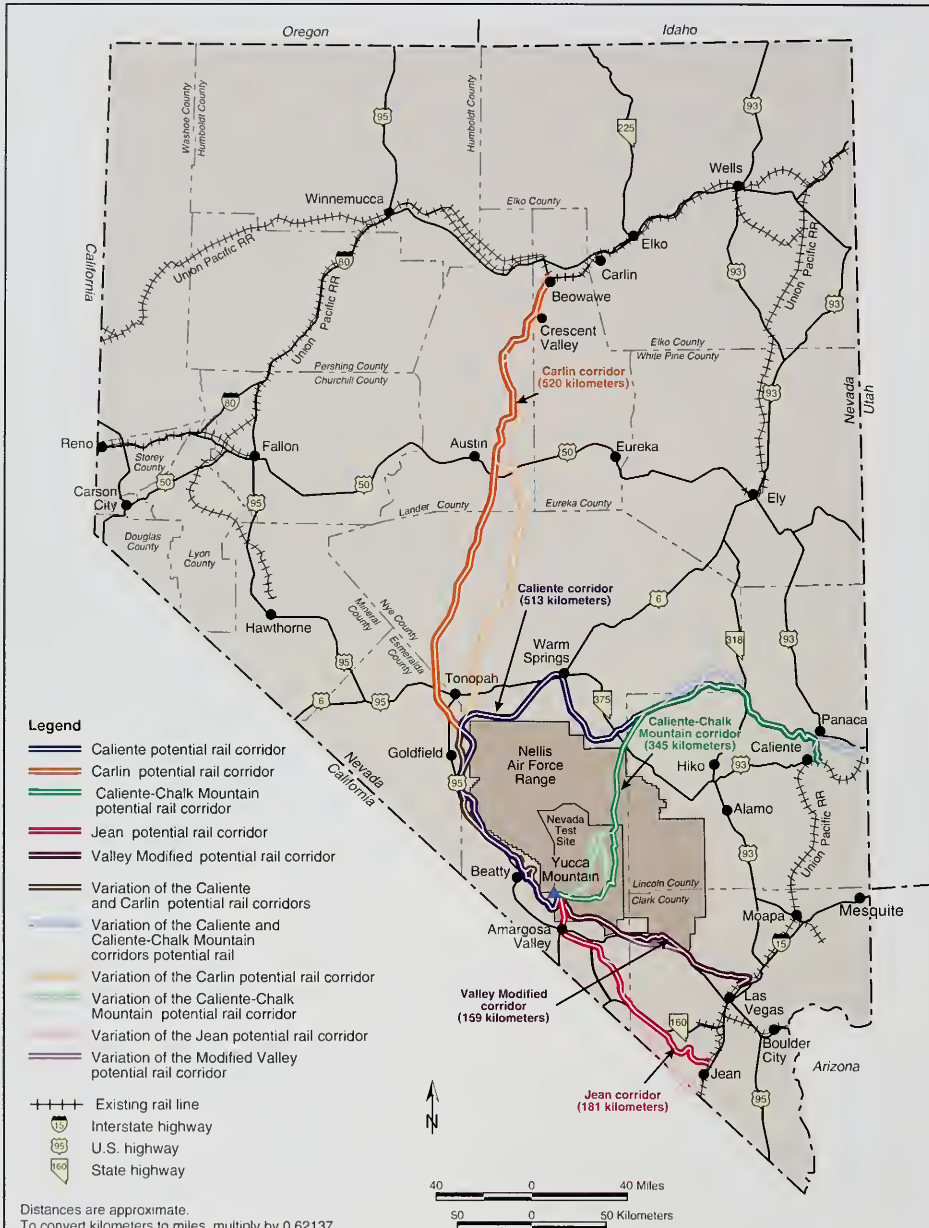


Figure S-13. Potential Nevada rail routes to Yucca Mountain.

Legend

- Potential heavy-haul route
- Highway
- Rail line
- Flow of inbound shipments
- State line
- County line
- Yucca Mountain

Potential heavy-haul routes in Nevada are highways identified by the Nevada Department of Transportation for shipments of overweight and overdimensional loads. The Nevada Department of Transportation would issue permits that specified approved routing for heavy-haul truck shipments on Nevada highways. The State of Nevada could designate alternative routes as specified in 49 CFR 397.103.

To convert kilometers to miles, multiply by 0.62137.

Figure S-14. Potential intermodal transfer station locations and potential routes in Nevada for heavy-haul trucks.

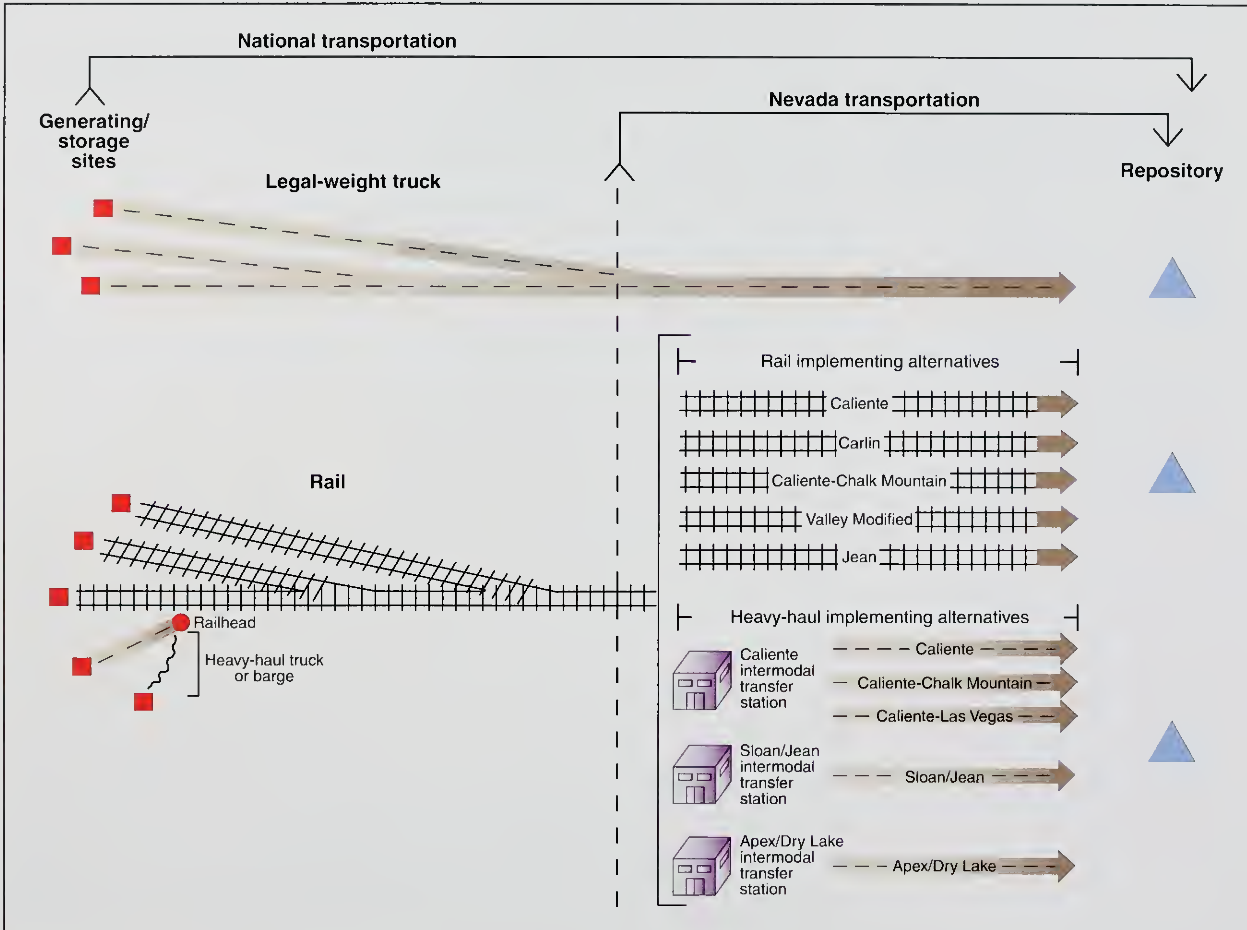


Figure S-15. Relationship of Nevada and national transportation.

- Scenario 2 assumes that spent nuclear fuel and high-level radioactive waste would remain at the 77 sites in perpetuity, but under institutional control for only about 100 years. This scenario assumes no effective institutional control of the stored spent nuclear fuel and high-level radioactive waste after 100 years.

DOE recognizes that neither scenario would be likely if there were a decision not to develop a repository at Yucca Mountain; however, they are part of the EIS analysis to provide a baseline for comparison to the Proposed Action. There are a number of possibilities that the Nation could pursue, including continued storage of the material at its current locations or at one or more centralized location(s); the study and selection of another location for a deep geologic repository; development of new technologies; or reconsideration of other disposal alternatives to deep geologic disposal. However, any of these potential actions are speculative, and DOE therefore did not evaluate them in the EIS. Under any future course that would include continued storage, both commercial and DOE sites have an obligation to continue managing the spent nuclear fuel and high-level radioactive waste in a manner that protects public health and safety and the environment.

S.3.2.1 Reclamation and Decommissioning at Yucca Mountain

Under the No-Action Alternative, site characterization activities would end at Yucca Mountain. DOE would start site decommissioning and reclamation. These activities would include the removal or shutdown of all surface and subsurface facilities, and the restoration of the lands disturbed during site characterization. DOE would fill and seal drill holes to meet Nevada requirements.

S.3.2.2 Continued Storage at Commercial and DOE Sites

Under the No-Action Alternative, the 72 commercial and 5 DOE sites would continue to store spent nuclear fuel and high-level radioactive waste. For purposes of analysis, the No-Action Alternative assumes that those sites would treat and package the materials, as necessary, for their safe onsite management. It also assumes that the amount of spent nuclear fuel and high-level radioactive waste stored would be the same as that shipped under the Proposed Action (70,000 MTHM).

The EIS analysis assumed that spent nuclear fuel and high-level radioactive waste would be placed in dry-storage canisters inside reinforced concrete storage modules. Both the canister and the concrete storage module would provide shielding against the radiation that the material would emit, although the concrete module would provide the primary shielding. The dry configuration would enable outside air to circulate and remove the heat of radioactive decay. As long as spent nuclear fuel, high-level radioactive waste, canisters, and storage modules were properly maintained, this would provide safe storage.

No-Action Scenario 1. Spent nuclear fuel and high-level radioactive waste would remain in dry storage at the commercial and DOE sites and would be under institutional control for at least 10,000 years. Institutional control at these facilities would ensure the protection of workers and the public in accordance with Federal regulations. For purposes of analysis, DOE assumed that the storage facilities would undergo one major repair during the first approximately 100 years, and complete replacement after the first 100 years every 100 years thereafter.

No-Action Scenario 2. Spent nuclear fuel and high-level radioactive waste would remain in dry storage at the commercial and DOE sites and would be under institutional control for approximately 100 years (as in Scenario 1). This scenario, however, assumes no effective institutional control after 100 years, and that the storage facilities at 72 commercial and 5 DOE sites would begin to deteriorate after 100 years. The facilities would eventually release radioactive materials to the environment, contaminating the atmosphere, soil, surface water, and groundwater for the 10,000-year period analyzed.

The assumption for Scenario 2 that there would be no effective institutional control after approximately 100 years is based on a review of generally applicable requirements that discount altogether the consideration of institutional control after 100 years for purposes of conducting performance assessments [U.S. Environmental Protection Agency regulations (40 CFR Part 191); U.S. Nuclear Regulatory Commission regulations for disposal of low-level radioactive material (10 CFR Part 61); and the National Research Council report on standards for the proposed Yucca Mountain Repository]. Thus, in addition to its inherent conservatism, the assumption that no institutional control would be in place after 100 years provides a consistent analytical basis for comparing the No-Action Alternative and the Proposed Action.

Figure S-16 shows conceptual timelines for activities at the commercial and DOE sites for Scenarios 1 and 2.

S.3.2.3 Costs

DOE estimates that the total cost of Scenario 1 or 2 for the first 100 years, including the decommissioning and reclamation of the Yucca Mountain site, would range from $51.5 billion to $56.7 billion, depending on the need to replace the dry-storage canisters in addition to replacing the storage facilities during that time. The estimated cost for the remaining 9,900 years of Scenario 1 would range from $480 million to $529 million per year. There would be no costs under Scenario 2 after the first 100 years because that scenario assumes no effective institutional control after that time.

S.4 Environmental Consequences of the Proposed Action

To analyze the potential environmental impacts associated with the Proposed Action, DOE compiled baseline information for various environmental resource areas and examined how the construction, operation and monitoring, and eventual closure of a repository at Yucca Mountain could affect each of those environmental resources, and resulting impacts on human health. In considering the impacts on human health, DOE analyzed both routine operations and accident scenarios.

ENVIRONMENTAL CONSEQUENCES AND PERIODS OF ANALYSIS

Short-term consequences are those that could occur in the period before the completion of repository closure, or approximately 100 years after the start of waste emplacement. DOE analyzed potential short-term impacts that could occur in resource areas as a result of performance confirmation, construction, operation and monitoring, closure, and transportation activities.

Long-term consequences are those that could occur after repository closure. DOE analyzed potential long-term impacts that could occur to human health and biological resources from radiological and chemical groundwater contamination for 10,000 years after repository closure. In addition, peak dose to 1 million years was estimated.

DOE conducted a broad range of studies to obtain or evaluate the information needed for the assessment of Yucca Mountain as a geologic repository. These studies have provided in-depth knowledge about the Yucca Mountain site and vicinity and provide sufficient information to aid in DOE decisionmaking. The Department used the information from these studies in the analyses described in this EIS. However, because some of these studies are ongoing, some of the information is incomplete. Further, the complexity and variability of the natural system at Yucca Mountain, the long period evaluated (10,000 years), and incomplete information or the unavailability of some information have resulted in uncertainty in the analyses and findings. Throughout the EIS, DOE notes both the use of incomplete information if complete information is unavailable, and the existence of uncertainty, to enable the reader to better understand EIS findings.

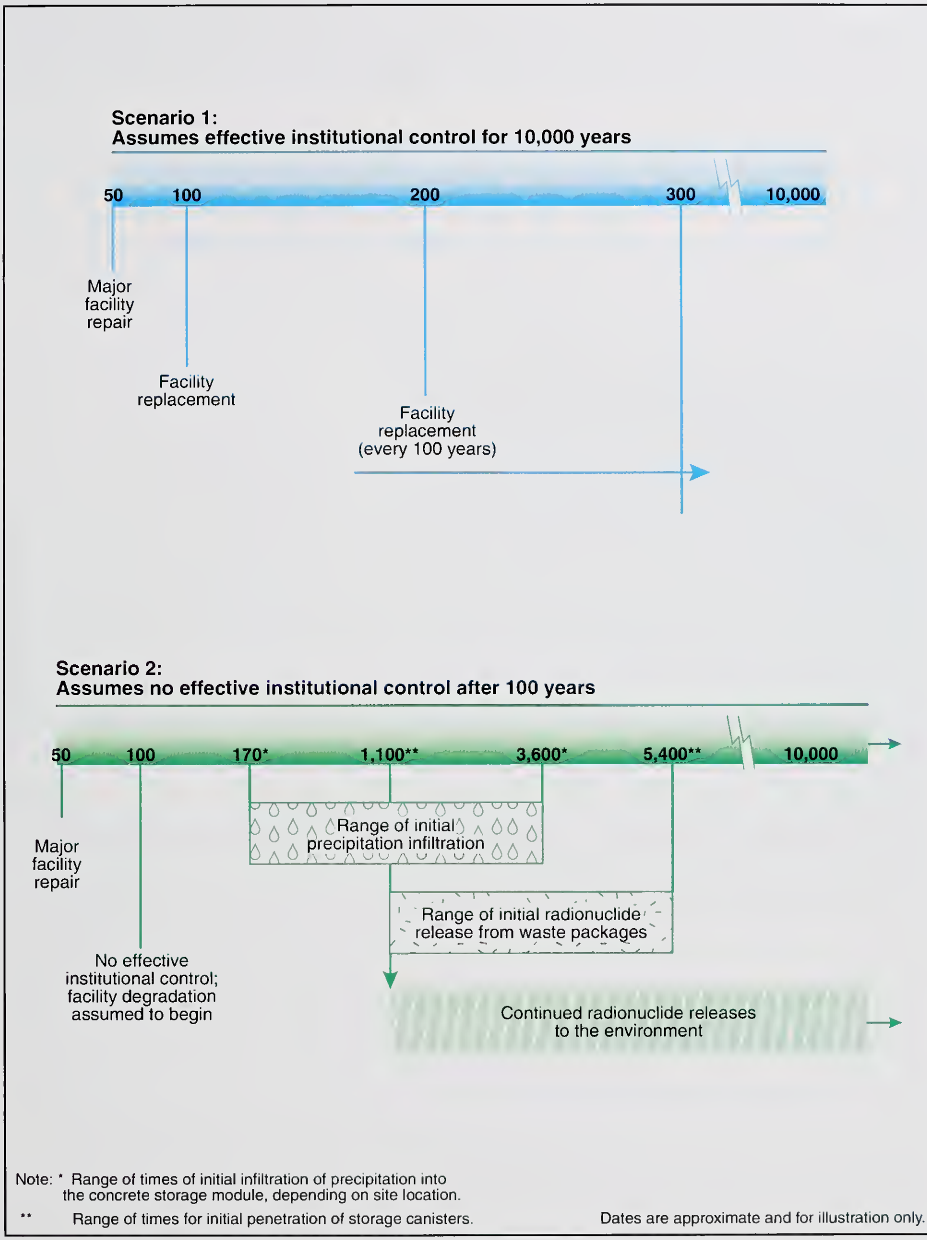


Figure S-16. Conceptual timelines for events at commercial and DOE sites for No-Action Scenarios 1 and 2.

The following paragraphs describe the potentially affected resources at the Yucca Mountain site and vicinity and a summary of the extent to which the Proposed Action could affect those resources.

S.4.1 YUCCA MOUNTAIN SITE AND VICINITY

The Yucca Mountain site is on Federal land in a remote area of the Mojave Desert in Nye County in southern Nevada, about 160 kilometers (100 miles) northwest of Las Vegas, Nevada. The Yucca Mountain region is sparsely populated and receives only about 10 to 25 centimeters (4 to 10 inches) of precipitation each year. The Yucca Mountain Repository land withdrawal area would occupy about 600 square kilometers (230 square miles or 150,000 acres) of land currently under the control of DOE, the U.S. Air Force, and the Bureau of Land Management.

SITE-RELATED TERMS

Yucca Mountain site (the site): The area on which DOE has built or would build the majority of facilities or cause the majority of land disturbances related to the proposed repository.

Yucca Mountain vicinity: A general term used in nonspecific discussions about the area around the Yucca Mountain site. The EIS also uses terms such as area, proximity, etc., in a general context.

Land withdrawal area: An area of Federal property set aside for the exclusive use of a Federal agency. For the analyses in this EIS, DOE used an assumed land withdrawal area of 600 square kilometers, or 150,000 acres.

Region of influence (the region): A specialized term indicating a specific area of study for each of the resource areas that DOE assessed for the EIS analyses.

Note: Not to scale

Surface repository facilities would occupy about 3.5 square kilometers (1.4 square miles or 870 acres) of the Yucca Mountain site. The remainder of the site would be used to locate support facilities, and for continued performance confirmation testing (for example, wells) and to separate repository facilities from other human activities. Performance confirmation activities would take place on and in the vicinity of the site. The existing environment at the site includes the structures and physical disturbances from DOE-sponsored activities that took place from 1977 to 1988 related to the selection of Yucca Mountain for site characterization, and continuing site characterization activities that began in 1989 to determine the suitability of the site for a repository.

S.4.1.1 Land Use and Ownership

The Yucca Mountain site is in the southwest corner of the DOE Nevada Test Site, adjacent to the Nellis Air Force Range. The lands in the region include Bureau of Land Management special-use areas excluded from development that would require terrain alterations, unless the alterations would benefit wildlife or public recreation. The Fish and Wildlife Service of the U.S. Department of the Interior manages the Desert National Wildlife Range and the Ash Meadows National Wildlife Refuge, which are about 48 kilometers (30 miles) east and 39 kilometers (24 miles) south of Yucca Mountain, respectively.

These areas provide habitat for a number of resident and migratory animal species in relatively undisturbed natural ecosystems. The National Park Service manages Death Valley National Park, which at its closest point is about 35 kilometers (22 miles) southwest of Yucca Mountain. The National Park Service also manages the small Devils Hole Protective Withdrawal in Nevada south of Ash Meadows.

State-owned lands are limited in the vicinity of the proposed repository. There are scattered tracts of private land in and near the towns of Beatty, Amargosa Valley, and Indian Springs in Nevada. There are larger private tracts in the agricultural areas of the Las Vegas Valley, near Pahrump, and in the Amargosa Desert south of the town of Amargosa Valley. The closest year-round housing is at Lathrop Wells, about 22 kilometers (14 miles) south of the site. There are farming operations about 30 kilometers (19 miles) south of the proposed repository in the town of Amargosa Valley. Figure S-17 shows the land use and ownership in the Yucca Mountain region.

Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. If the Yucca Mountain site were recommended for development as a repository, a permanent land withdrawal would be necessary to isolate the land designated for the site from public access to satisfy Nuclear Regulatory Commission licensing requirements. The EIS analysis assumed the use of an area of approximately 600 square kilometers (150,000 acres) on Bureau of Land Management, U.S. Air Force, and DOE lands in the vicinity of the proposed repository. Performance confirmation, repository construction, operation and monitoring, and closure activities would require the use of about 3.5 square kilometers (870 acres) of noncontiguous areas within the 600-square-kilometer (150,000-acre) area. These activities would not conflict with land uses on adjacent lands.

RUBY VALLEY TREATY ISSUE

The Western Shoshone people maintain that the Ruby Valley Treaty of 1863 gives them rights to certain lands, including the Yucca Mountain region. The Western Shoshone filed a claim in the early 1950s alleging that the Government had taken the tribe's land. The Indian Claims Commission found that Western Shoshone title to the land had gradually been extinguished, and set a monetary award as payment for the land. In 1976, the Commission granted a final award to the Western Shoshone people. The Western Shoshone dispute these findings, and have not accepted the monetary award for the lands in question. The tribe maintains that no payment has been made and that Yucca Mountain is on Western Shoshone land. Although DOE recognizes the sensitivity of this issue, it must abide by rulings that have been made by the U.S. Supreme Court, which in 1985 held that payment had been made in accordance with the Indian Claims Commission Act of 1946. This constituted full and final settlement for the land. DOE is aware that among the Native American community there is significant disagreement with the Court rulings.

S.4.1.2 Air Quality

The evaluation of impacts to air quality considered potential releases of nonradiological and radiological pollutants associated with the Proposed Action and doses to maximally exposed individuals and populations of the public and noninvolved workers (workers who could be exposed to air emissions from repository activities but who would not be directly associated with those activities). Involved workers are discussed in Section S.4.1.8. The EIS also discusses potential long-term human health impacts from exposure to these releases.

Nonradiological Impacts. Sources of nonradiological air pollutants at the proposed repository site could include fugitive dust emissions from land disturbances, excavated rock handling, and concrete batch plant operations and emissions from fossil fuel consumption. Nonradiological air quality impacts could include those from criteria pollutants, including nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter with a diameter of less than 10 micrometers (PM_{10}), and from other potentially harmful material such as cristobalite, a form of silica dust that can cause a respiratory disease known as silicosis

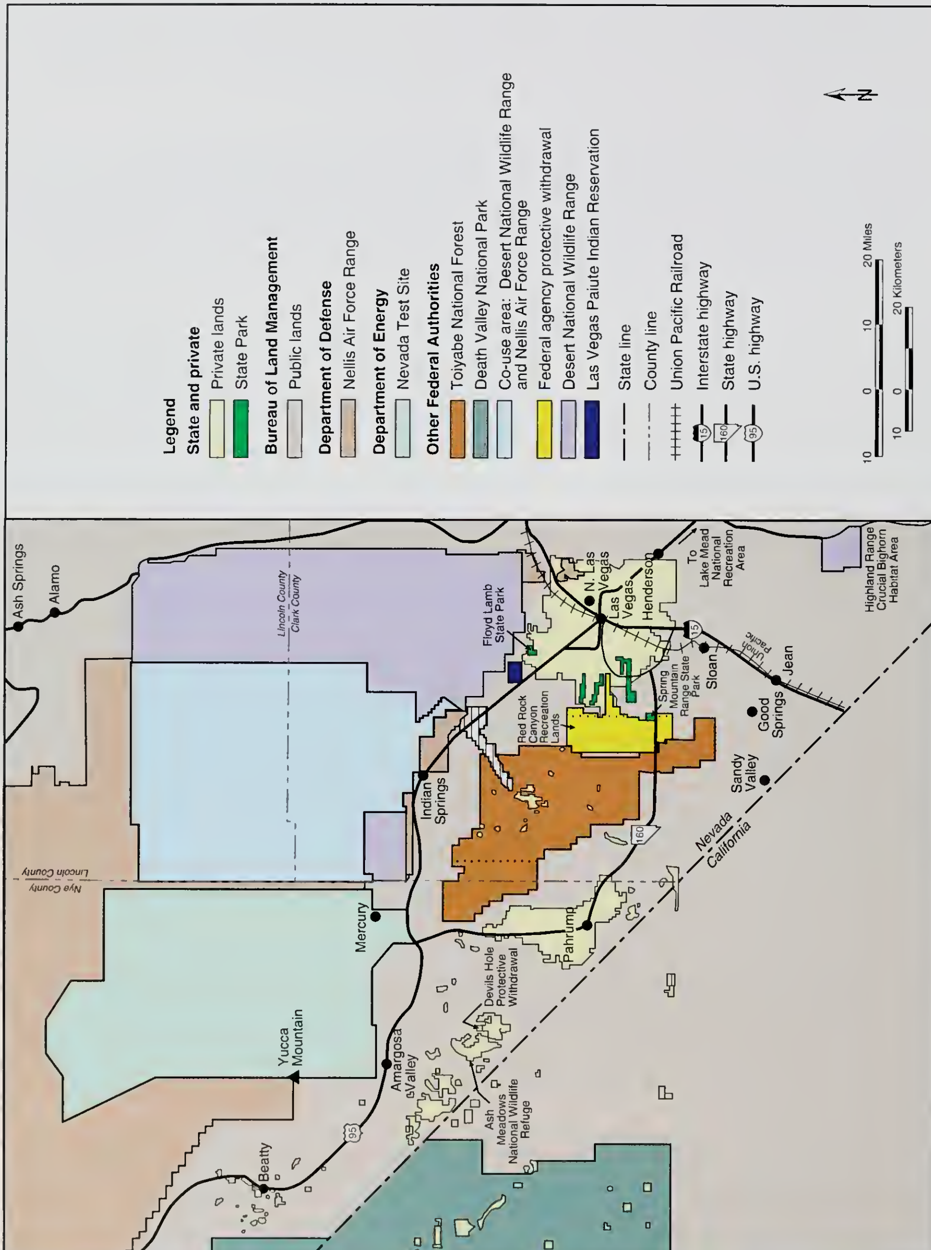


Figure S-17. Land use and ownership in the Yucca Mountain region.

and that might be a carcinogen. DOE compared the potential releases to the new U.S. Environmental Protection Agency National Ambient Air Quality Standard for particulate matter with a diameter of less than 2.5 micrometers. A Federal appeals court recently struck down these new standards. [See American Trucking Association, Inc. v. EPA, No. 97-1440 (D.C. Cir. May 14, 1999).] However, the EIS used these standards, among other standards that were not at issue in that case, in analyzing air quality impacts.

DOE analyzed nonradiological air quality impacts at the potential locations of maximally exposed members of the public. Exposures of maximally exposed individuals to airborne pollutants would be a small fraction of applicable regulatory limits established by the U.S. Environmental Protection Agency. There are slight differences in estimated concentrations for the different thermal loads and different packaging scenarios; however, these do not show meaningful distinctions among any of the scenarios.

Cristobalite would be emitted from the subsurface in exhaust ventilation air during excavation operations and would be released as fugitive dust from the excavated rock pile, so members of the public and noninvolved workers could be exposed. Fugitive dust from the excavated rock pile would be the largest potential source of cristobalite exposure to the public. The postulated annual average exposure of the hypothetical maximally exposed member of the public to cristobalite from construction activities would be small, ranging from 0.01 to 0.03 microgram per cubic meter for the different thermal load scenarios. DOE would use common dust suppression techniques (water spraying, etc.) to reduce releases of fugitive dust from the excavated rock pile.

Radiological Impacts. Radiological air quality impacts could occur from releases of radionuclides, primarily naturally occurring radon-222 and its radioactive decay products, which would be released from the rock into the subsurface facility and then into the ventilation air during all phases of the repository project.

No releases of manmade radionuclides would occur during the construction phase because such materials would not be present until repository operations began. However, there would be naturally occurring radon-222 and its radioactive decay products in the air exhausted from the subsurface. Exposure to naturally occurring radon-222 results in an annual average individual dose in the United States of about 200 millirem. In the subsurface, radon-222 would leave the rock and enter the drifts, from which it would be exhausted as part of repository ventilation. Total estimated radon releases during construction would increase as the thermal load decreased because the excavated volume of the repository would increase as the thermal load decreased. The dose to an offsite maximally exposed individual member of the public would be approximately 0.49 millirem per year; the dose to the maximally exposed noninvolved worker would be approximately 5.4 millirem per year.

During the early years of the operation and monitoring phase, the handling of spent nuclear fuel and continued subsurface ventilation would result in radionuclide releases. Radionuclides, primarily krypton-85 and small amounts of carbon-14, would be released during the transfer of fuel assemblies from transportation casks to disposal containers in the Waste Handling Building. Releases would vary from 90 to 2,600 curies annually depending on the packaging scenario.

A continuing source of doses to members of the public and noninvolved (surface) workers during the operation and monitoring phase would be releases of naturally occurring radon-222 from the subsurface. Estimated radon emissions during this phase would be greater than those during the construction phase because of the larger excavated volume, with more radon emanations from the repository walls and greater quantities exhausted by ventilation. Doses to an offsite maximally exposed individual member of the public and to the maximally exposed noninvolved worker would be highest under the low thermal load scenario (about 1.8 and 3.4 millirem per year, respectively, during the handling, emplacement, and development activities of the operation and monitoring phase).

RADIATION

In the United States, people are inevitably exposed to three sources of ionizing radiation: natural sources unaffected by human activities, such as cosmic radiation from space and natural radiation in the ground (for example, that from radon); sources of natural origin but affected by human activities, such as air travel and tunneling through rocks as at Yucca Mountain; and manmade sources, such as medical X-rays and consumer products. In the Yucca Mountain region, individuals are typically exposed to a 340- to 390-millirem radiation dose from natural and manmade sources each year, compared to about 300 millirem for the average person living in other areas of the United States.

When a person is exposed to radioactive material, the amount of ionizing radiation absorbed by the body is called the radiation *dose*. Dose is often described in measurement units of *rem*, which take into account how different types of radiation affect the body (the biological effectiveness). Small doses are described in *millirem*, each of which is one one-thousandth of a rem.

To analyze the impact of exposure to radiation, DOE used a hypothetical *maximally exposed individual* (member of the public, involved worker, or noninvolved worker), defined as the individual whose location and habits result in the highest potential total radiation dose from a particular source for all exposure routes (inhalation, ingestion, direct exposure).

The dose to members of the public from repository operations would vary by thermal load scenario but not by packaging scenario because naturally occurring radon-222 released from the subsurface would be the dominant dose contributor. Releases from surface facilities during spent nuclear fuel handling would make small differences in the dose received.

During the closure phase, repository subsurface facilities would continue to be ventilated for a period of time. The only doses from releases of radionuclides to the atmosphere would be from naturally occurring radon-222 and its radioactive decay products released from the continued ventilation of subsurface facilities. Doses to an offsite maximally exposed individual member of the public and to the maximally exposed noninvolved worker would be highest under the low thermal load scenario (about 1.2 and 0.12 millirem per year, respectively). The hypothetical maximally exposed individual member of the public would receive a higher dose than the noninvolved worker maximally exposed individual because air would be removed from the repository through exhaust shafts, which would result in more radon being carried to the exposure point for the offsite individual than to that for the noninvolved worker.

S.4.1.3 Geology

Yucca Mountain is a product of volcanic activity that occurred 11.4 million to 14 million years ago and subsequent seismic faulting. The mountain is bordered on the north by Pinnacles Ridge and Beatty Wash, on the west by Crater Flat, on the south by the Amargosa Valley, and on the east by Jackass Flats, which contains Fortymile Wash. Beatty Wash is one of the largest tributaries of the Amargosa River and drains the region north and west of Pinnacles Ridge, a part of Yucca Mountain that is north of the proposed repository. Fortymile Wash is the most prominent drainage through Jackass Flats to the Amargosa River. The river is dry along most of its length most of the time. Figure S-18 shows the physiographic subdivisions and characteristic land forms in the region of influence for geology.

DOE would build the proposed repository and emplace the waste packages in a mass of volcanic rock (welded tuff) known as the Topopah Springs Formation. This formation was formed by a volcanic ash-flow from the calderas north of Yucca Mountain 12.8 million years ago and has not been disturbed by volcanic activity since then. The volcanic activity that produced these rocks is complete and, based on the geology of similar volcanic systems in the region, additional silicic activity would be unlikely. (Younger, small-volume basaltic volcanoes to the north and west of Yucca Mountain have been the focus

VOLCANISM

Differing views on the likelihood of volcanism near Yucca Mountain result from uncertainty in the volcanic hazard assessment. To address these uncertainties, DOE has performed analyses, conducted extensive volcanic hazard assessments, considered alternative interpretations of the geologic data, and consulted with recognized experts. In 1995 and 1996, DOE convened a panel of recognized experts representing other Federal agencies (for example, the U.S. Geological Survey and national laboratories) and universities (for example, the University of Nevada and Stanford University) to assess uncertainties associated with the data and models used to evaluate the potential for disruption of the proposed Yucca Mountain Repository by a volcanic intrusion. The panel estimated that the chance of a volcanic disruption at or near the repository during the first 10,000 years after closure would be 1 in 7,000.

of extensive study by DOE.) DOE chose the Topopah Springs formation as the repository host rock because of (1) its depth below the ground surface that would protect nuclear materials from exposure to the environment, (2) its extent and characteristics that would enable the construction of stable openings and the accommodation of a range of temperatures, (3) its location away from major faults that could adversely affect the stability of underground openings and could provide pathways for water flow, eventually leading to radionuclide release, and (4) its location well above the present water table.

North-trending seismic faults are the characteristic geological structural elements at Yucca Mountain. The Solitario Canyon fault forms the major bounding fault on the west side of Yucca Mountain, and volcanic units in the mountain tilt eastward as a result of the displacement along this and lesser faults through the mountain. One relatively short, northwest-trending subsidiary fault, the Sundance fault, and the north-trending intrablock Ghost Dance fault transect the region. Studies at Yucca Mountain indicate that individual faults have very long recurrence intervals between the types of earthquakes that would be powerful enough to cause surface displacements. Strain can accumulate on these faults over long periods between surface-rupturing earthquakes. Little or no seismic activity might occur during this long strain buildup.

EARTHQUAKES

Experts have evaluated site data and other relevant information to assess where and how often future earthquakes could occur, how large they could be, how much offset could occur at the Earth's surface, and how much ground motion could diminish as a function of distance. DOE will use these results to design the repository to withstand the effects of earthquakes that might occur in the future.

DOE has monitored seismic activity at the Nevada Test Site since 1978. In 1992, an earthquake measuring 5.6 on the Richter scale occurred at Little Skull Mountain, about 20 kilometers (12 miles) southeast of Yucca Mountain. It caused no detectable damage in tunnels at either the Yucca Mountain site or the Nevada Test Site or at characterization facilities at the Yucca Mountain site.

S.4.1.4 Hydrology

Yucca Mountain is in the Death Valley hydrologic basin, which is within the larger area of the Great Basin. This area is characterized by a very dry climate, limited surface water, and deep aquifers. The Death Valley basin is a closed hydrologic basin, which means its surface water and groundwater can leave only by evaporation from the soil and other surfaces and transpiration from plants. Surface-water resources include drainages and streambeds, streams, springs, and playa lakes. The groundwater system includes recharge zones (where water infiltrates from the surface and reaches the saturated zone and aquifers), discharge points (where groundwater reaches the surface), unsaturated zones (above the water table), saturated zones (below the water table), and aquifers (water-bearing layers of rock that can provide water in usable quantities).

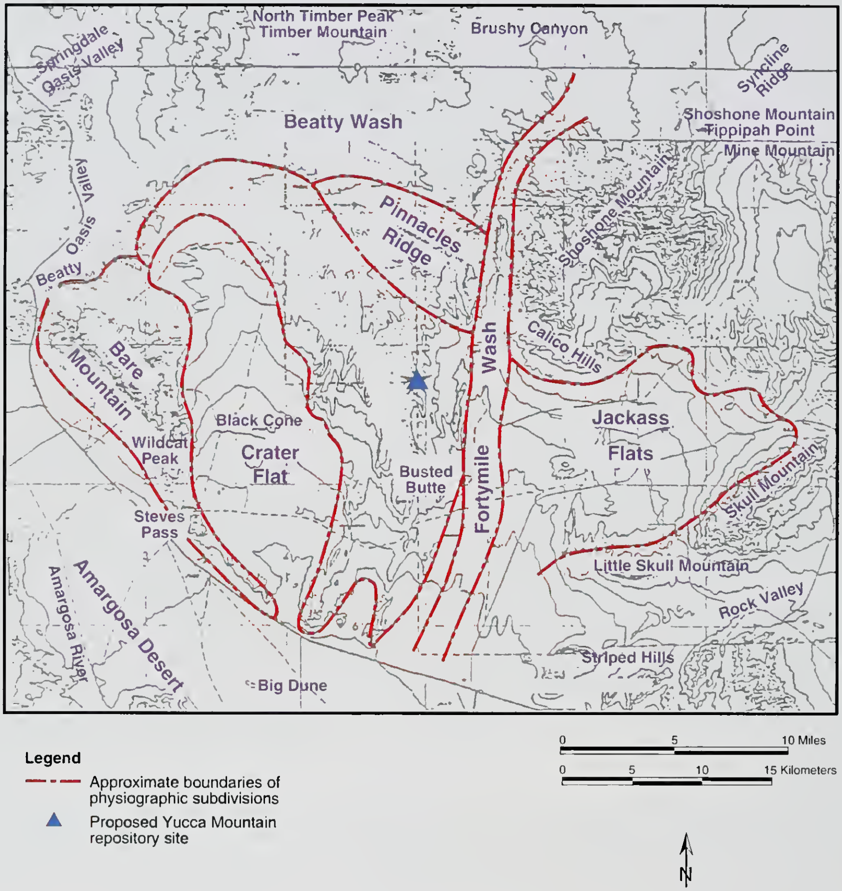


Figure S-18. Physiographic subdivisions of the Yucca Mountain area.

Surface Water. Yucca Mountain and the Death Valley Basin, like other areas in the southern Great Basin, generally lack year-around streams and other surface-water bodies. The Amargosa River system drains Yucca Mountain and the surrounding areas. Although referred to as a river, the Amargosa and its tributaries (the washes that drain to it) are dry most of the time.

Activities associated with the Proposed Action could cause minor impacts to surface hydrology at the Yucca Mountain site. The potential for contaminants to reach surface water generally would be limited to spills or leaks followed by a rare precipitation or snow melt event large enough to generate runoff. The most likely sources of potential surface-water contaminants would be the fuels (diesel and gasoline) and lubricants (oils and greases) needed for equipment. Because these materials would be used and stored inside buildings and managed in accordance with standard best management practices, there would be little potential for contamination to spread to surface water.

Disturbing the land surface probably would alter the rate at which water could infiltrate the surface. Of the approximately 3.5 square kilometers (1.4 square miles or 870 acres) needed for surface repository facilities, construction and operation and monitoring activities probably would disturb about 2 square kilometers (500 acres). However, DOE expects the resulting change in the amount of runoff actually reaching the drainage channels to be relatively minor because repository activities would disturb a relatively small amount of the natural drainage area. The eventual removal of structures and impermeable surfaces, with mitigation (soil reclamation) and rehabilitation of natural plants in disturbed areas, would decrease runoff from these areas.

Facilities at which DOE would manage radioactive materials would be able to withstand the probable maximum flood (the most severe flood that is reasonably foreseeable). The foundations would be built up as necessary so the facilities would be above the flood level. Other facilities would be designed and built to withstand a 100-year flood, consistent with common industrial practice. The water levels expected from a 100-year, 500-year, or probable maximum flood would be unlikely to reach the North and South Portal Operations Areas.

Portions of the transportation system probably would be in the 100-year floodplains of Midway Valley Wash, Drillhole Wash, Busted Butte Wash, and/or Fortymile Wash. Structures that might be constructed in a floodplain could include one or more bridges to span the washes, one or more roads that could pass through the washes, or a combination of roads and culverts in the washes. Based on an initial assessment, potential impacts from such activities would be minor. When more specific information becomes available about activities proposed to take place in floodplains and wetlands, DOE will conduct further environmental review in accordance with a floodplain/wetlands review requirement (10 CFR Part 1022).

Groundwater. The groundwater flow system of the Death Valley region is very complex, involving many groundwater basins, as shown in Figure S-19. Over distance, these layers vary in their characteristics or even their presence. In some areas, confining units allow considerable movement between aquifers; in other areas confining units are sufficiently tight to support artesian conditions (where water in a lower aquifer is under pressure in relation to water in an overlying aquifer).

Groundwater in aquifers below Yucca Mountain and in the surrounding region flows generally south toward discharge areas in the Amargosa

GROUNDWATER

Aquifer: A subsurface saturated rock unit of sufficient permeability to transmit groundwater and capable of yielding usable quantities of water to wells and springs.

Confining unit: A rock or sediment layer that restricts the movement of water into or out of adjacent aquifers.

Spring: A point (sometimes a small area) through which groundwater emerges from an aquifer to the ground surface.

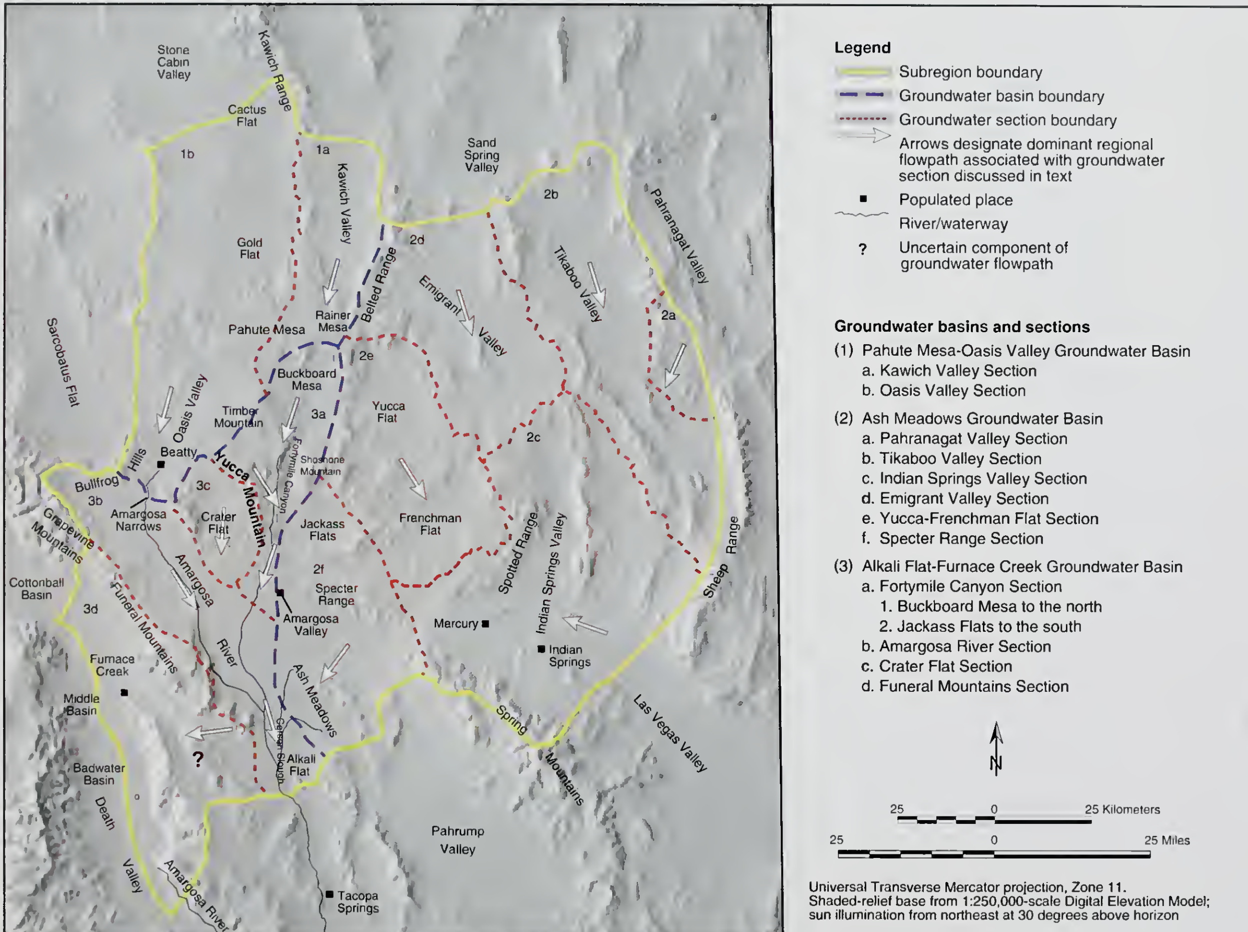


Figure S-19. Groundwater basins in the Yucca Mountain vicinity.

Desert and Death Valley. This broad area is called the Death Valley groundwater basin. The area around Yucca Mountain is in the central portion of the regional groundwater basin, which has three sub-basins: (1) Pahute Mesa-Oasis Valley, (2) Ash Meadows, and (3) Alkali Flat-Furnace Creek Ranch.

There is scientific uncertainty about the exact locations of the groundwater flow boundaries between the three sub-basins in the Death Valley groundwater basin. All interpretations of the available data, however, place the aquifers below Yucca Mountain in the central Alkali Flat-Furnace Creek Ranch sub-basin. In the region of influence for hydrology, the primary sources of groundwater recharge are infiltration on Pahute Mesa, Timber Mountain, and Shoshone Mountain to the north, and the Grapevine and Funeral Mountains to the south. Recharge in the immediate Yucca Mountain vicinity is small in comparison and consists of water reaching Fortymile Wash as well as precipitation that infiltrates the surface. DOE studies indicate that the quantity of water that might move through a repository area of 10 square kilometers (2,500 acres), assuming 6.5 millimeters (0.3 inch) of infiltration per year, would be about 0.3 percent of the estimated 23.4 million cubic meters (19,000 acre-feet) that moves from the Amargosa Desert to Death Valley on an annual basis.

To pose a threat to groundwater, a contaminant would have to be spilled or released and then carried down either by its own weight or by infiltrating water. The depth to groundwater and the arid environment would combine to reduce the potential for meaningful contaminant migration.

The most likely way to affect infiltration rates and, thus, groundwater recharge would be as the result of a land disturbance that caused additional runoff from the facilities to accumulate in areas like Fortymile Wash. That is, the additional runoff could increase groundwater recharge. However, given the dry climate and relatively small amount of potentially disturbed area in relation to the surrounding unchanged areas, the net change in infiltration would be small. After closure, the implementation of soil reclamation and revegetation would accelerate a return to more natural infiltration conditions.

DOE would meet the water demand for the Proposed Action by pumping from the groundwater in the Jackass Flats area. The perennial yield of the aquifer (the estimated quantity of groundwater that can be withdrawn annually without depleting the reservoir) in the Jackass Flats area is between 1.1 million and 4.9 million cubic meters (890 and 4,000 acre-feet). The highest demand during repository construction added to the demand from ongoing Nevada Test Site activities would be below the lowest estimate of the area's perennial yield.

However, repository water demands during emplacement and development activities, when combined with the baseline demands from Nevada Test Site activities, would exceed the lowest perennial yield estimate under the low thermal load for all packaging scenarios. The combined water demand under the high or intermediate thermal load scenario would not exceed the lowest estimates of perennial yield. None of the water demand estimates would approach the high estimates of perennial yield.

S.4.1.5 Biological Resources and Soils

The plants and animals in the Yucca Mountain vicinity are typical of species in the Mojave and Great Basin Deserts. No plants listed as *threatened* or *endangered*, that are proposed for listing, or that are candidate species under the Endangered Species Act occur in the land withdrawal area analyzed in this EIS. No plant species classified as *sensitive* by the Bureau of Land Management are known to occur in the analyzed land withdrawal area. Several species of cacti and yucca protected from commercial collection by the State of Nevada occur throughout the Yucca Mountain region, including the analyzed land withdrawal area. Neither the removal of vegetation from the small area required for the repository nor the impacts to some species would affect regional biological diversity and ecosystem function.

One animal that lives at the Yucca Mountain site, the desert tortoise, is listed as *threatened* under the Endangered Species Act. Yucca Mountain is at the northern edge of the range of the desert tortoise, and

the presence of tortoises at the site is infrequent in comparison to other portions of its range. DOE would continue to work with the Fish and Wildlife Service to minimize impacts to desert tortoises at the site. There is no critical habitat in the analyzed land withdrawal area.

Five animal species classified as *sensitive* by the Bureau of Land Management (two bats, a lizard, an owl, and a beetle) occur at the Yucca Mountain site. These species are unlikely to be affected by repository activities because loss of individuals would be rare or a small amount of habitat would be disturbed, depending on the species.

There would be small quantities of routine releases of radioactive materials from the repository. These releases would consist of gases, principally krypton and small amounts of carbon-14 from spent nuclear fuel and naturally occurring radon. The small quantities released would result in small doses to plants and animals as the gases dispersed in the atmosphere. The estimated doses would be unlikely to affect the population of any species.

There are no wetlands on the proposed repository site, so no impacts to such areas would occur as a result of repository construction, operation and monitoring, or closure. Soils at the site are from underlying volcanic rocks and mixed alluvium (sand, silt, or clay deposited on land by water) dominated by volcanic material, and in general have low water-holding capabilities. The potential for soil impacts such as erosion would increase slightly as a result of land-disturbing activities at the site, but DOE would use erosion control techniques to minimize impacts.

DOE also considered whether, during the postclosure period, the repository would affect biological resources at Yucca Mountain on the repository footprint through the heating of the ground surface and through radiation exposure to species from contaminant migration through groundwater to discharge points. After closure, heat from the decay of radionuclides in the waste would cause temperatures in the rock near the disposal containers to rise above the boiling point of water. The time that the subsurface temperature would remain above the boiling point would vary from a few hundred years (under the low thermal load) to a few thousand years (under the high thermal load). Conduction and the flow of heated air and water through the rock would carry the heat away from the disposal containers through the rock. The heat would spread to the surface above and to the aquifer below.

Although the atmosphere would remove excess heat when it reached the ground surface, the temperature of near-surface soils would be likely to increase slightly. Surface soil temperatures could increase by as much as approximately 3°C (5.4°F) in dry soil at a depth of 1 meter (3.3 feet), which could affect root growth and the growth of microbes or nutrient availability. Potential impacts from the repository on biological resources would consist of an increase of heat-tolerant species and a decrease of less heat-tolerant species. In general, areas affected by repository heating could experience a loss of shrub species and an increase in annual species. A shift in the plant community could also lead to localized changes in the animal community that depend on the plant community for food and shelter. The effects of repository heat on the surface soil temperatures would gradually decline with distance from the repository out to about 500 meters (1,640 feet). DOE expects any shift in species composition to be limited to that general area.

In the distant future (many thousands of years) groundwater would contain small quantities of radionuclides and chemically toxic substances. Because the estimated doses to humans exposed to this water would be very small, impacts to plants and animals would be small and unlikely to have adverse impacts on the population of any species.

Impacts to surface soils at Yucca Mountain in the postclosure period would be possible. If vegetation cover decreased as a result of the presence of the repository, the amount of rainfall runoff and the amount of sediment could be higher, thereby changing the surface-water quality in the Yucca Mountain area.

S.4.1.6 Cultural Resources

Land disturbances associated with the Proposed Action could have direct impacts on cultural resources around Yucca Mountain. Archaeological investigations in the immediate vicinity of the proposed surface facilities during characterization studies and infrastructure construction have identified 826 archaeological and historic sites. Most of the archaeological sites are small scatters of stone artifacts. None of the sites has been listed on the *National Register of Historic Places,* but 150 are potentially eligible.

Repository development would disturb no more than about 2 square kilometers (500 acres) of previously undisturbed land at the site. Before repository development activities began, DOE would identify and evaluate archaeological or cultural resources sites for their importance and eligibility for inclusion on the *National Register of Historic Places*. DOE would avoid such sites if possible or, if avoidance were not possible, DOE would conduct a data recovery program in cooperation with tribal representatives and other appropriate officials and would document the findings. Artifacts and knowledge from the site would be preserved. Improved access to the area could lead to indirect impacts, which could include unauthorized excavation or collection of artifacts. Training, which is ongoing during site characterization activities, would continue to be provided to workers on the laws and regulations related to the protection of cultural resources.

Studies have described several Native American sites, areas, and resources in or immediately adjacent to the analyzed land withdrawal area. DOE recognizes that Native Americans have concerns about protecting traditions and the spiritual integrity of the land in the Yucca Mountain region, and that these concerns extend to the propriety of the Proposed Action. The Consolidated Group of Tribes and Organizations in the area surrounding the Yucca Mountain site value the cultural resources in the area, viewing them in a holistic manner. They believe that the water, animals, plants, air, geology, sacred sites, and artifacts are interrelated and dependent on each other for existence. Because of the general level of importance attributed to the land by these Native Americans, and because they regard the land as part of an equally important integrated cultural landscape, these Native Americans consider the intrusive nature of the repository to be an adverse impact to all elements of the natural and physical environment. The establishment of the land withdrawal boundary and construction of the repository would continue to restrict their free access to these areas. Figure S-20 shows traditional boundaries and locations of tribes in the region.

S.4.1.7 Socioeconomics

Southern Nevada has been one of the fastest-growing areas in the country, with its economy being driven by the growth of the hotel and gaming industry. Most of the Yucca Mountain Project and Nevada Test Site onsite employees live in Clark (79 percent of employees), Lincoln (0.3 percent), and Nye (19 percent) Counties. Between 1980 and 1990, Clark County experienced a 4.8-percent annual growth rate (compared to 4 percent in Nevada and less than 1 percent in the United States as a whole), and added an average of 19,000 jobs per year. Since 1990, that pace has increased to more than 30,000 new jobs per year. Similarly, Nye County experienced a 3.7 percent annual growth rate, while Lincoln County's population increased by about 10 percent between 1990 and 1997. Because of the thousands of new jobs added to the economy each month, the area has a low unemployment rate. In addition, the residential housing market is strong and steady; steady employment and population growth are spurring the demand for housing. Public services such as education, health care, law enforcement, and fire protection are adequate. However, these services likely will require expansion if the general growth in the economy and population continues.

The DOE evaluation of impacts to the socioeconomic environment in communities in the vicinity of the proposed repository considered changes to employment, population, housing, and public services. The potential for changes in the socioeconomic environment would generally be on the order of a 1 to 5 percent change, depending on the attribute and the county. For example, the largest change in population

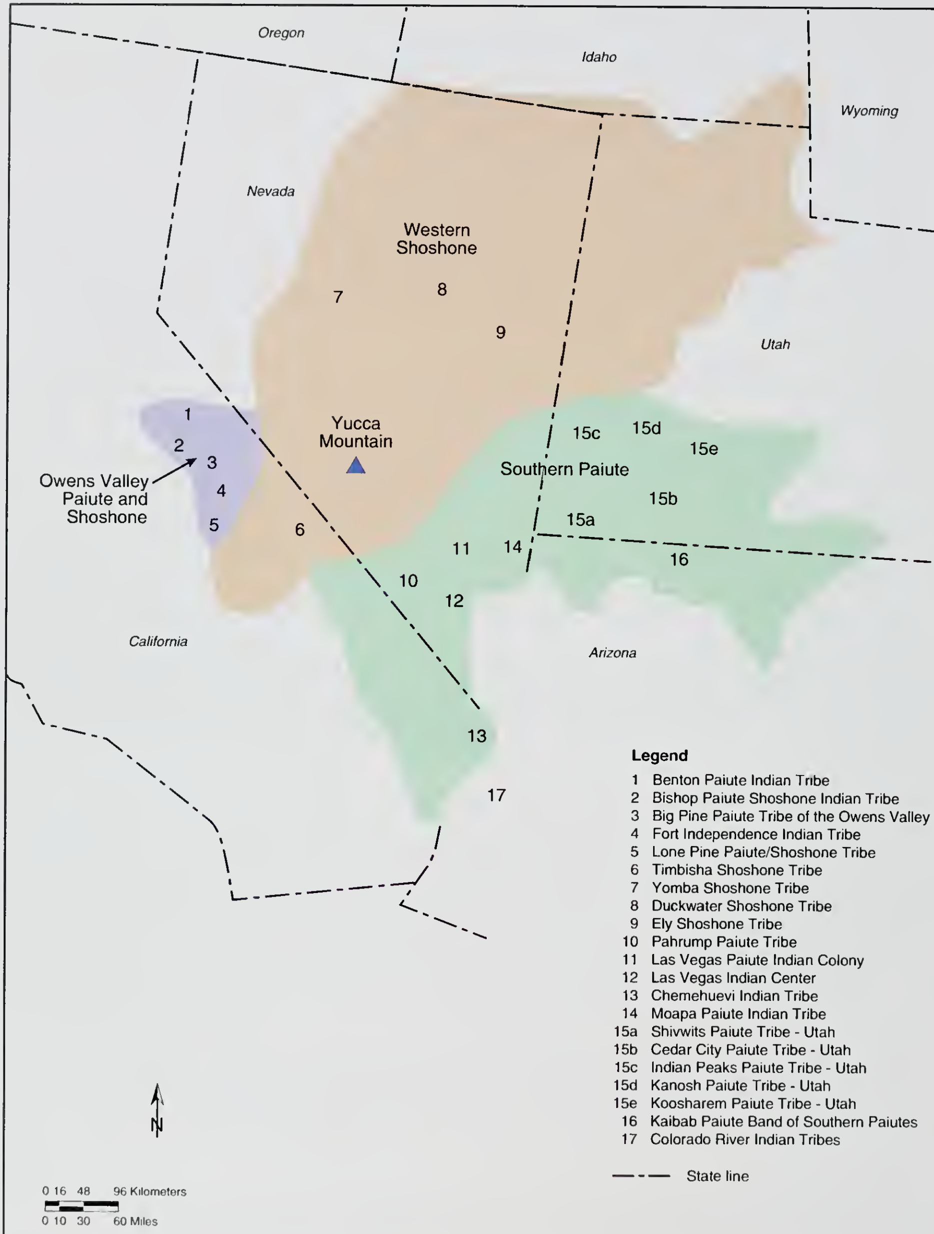


Figure S-20. Traditional boundaries and locations of tribes in the Yucca Mountain region.

would range from less than 1 percent in Clark County to about 2 percent in Nye County, to as high as 5.8 percent in Lincoln County (assuming the selection of a rail or heavy-haul transportation route in Lincoln County).

For the EIS analysis, DOE established a bounding case with which to examine the maximum potential employment levels it would need to implement design alternatives and packaging scenarios and to identify the combination that would produce the highest employment. This maximum employment case would be the combination of the low thermal load scenario and the uncanistered packaging scenario. The analysis of this bounding case determined that no large socioeconomic impacts would be likely. Maximum employment and population changes in the region as a result of the repository would not exceed one-half of 1 percent of the projected employment and population levels in 2000. Similarly, impacts to housing availability and public services from population changes in the region resulting from repository activities would be small.

S.4.1.8 Occupational and Public Health and Safety

The analysis of occupational and public health and safety considered short-term (about 100 years) health impacts from routine operations (1) to workers from hazards that are common to similar industrial settings and excavation operations, such as falling or tripping (referred to as industrial hazards), (2) to workers and the public from naturally occurring nonradiological materials in the rock under Yucca Mountain, (3) to workers as a result of exposure to radiation sources during their work activities, and (4) to the public from airborne releases of radionuclides (estimated doses are described in Section S.4.1.2). The analysis also considered involved workers (those who would participate in a particular activity) and noninvolved workers (those who would be on the site but would not participate directly in the activity in question). In addition, the analysis estimated impacts from radiological and nonradiological doses to a hypothetical maximally exposed member of the public at the site boundary 20 kilometers (12 miles) south of the repository, and the collective effect to the public within about 80 kilometers (50 miles).

HEALTH AND SAFETY IMPACTS

Workers
- Industrial hazards
  - Involved workers
  - Noninvolved workers
- Nonradiological impacts
  - Involved workers
  - Noninvolved workers
- Radiological impacts
  - Involved workers
  - Noninvolved workers

Public
- Nonradiological impacts
  - Maximally exposed individual
  - Population
- Radiological impacts
  - Maximally exposed individual
  - Population

Impacts to Workers from Industrial Hazards. Workers would be subject to industrial hazards during all phases of the Proposed Action. Examples of the types of industrial hazards that could present themselves include tripping, being cut on equipment or material, dropping heavy objects, and catching clothing in moving machine parts. Most impacts would be the result of surface facility operations (loading fuel at the Waste Handling Building) during the operation and monitoring phase, because a large fraction of the workers would be associated with surface facility operation. These workers would be mainly engaged in material handling operations in the Waste Handling Building. The next biggest component of industrial hazards would be the result of the excavation of drifts during the same phase. Other surface facility activities (equipment and facility maintenance), monitoring activities, and general office and industrial site activities would account for the remainder of the industrial hazard impacts.

The highest estimated total number of industrial hazards would occur under the combination of the low thermal load scenario and the uncanistered packaging scenario (1.9 fatalities). The lowest estimated total number would occur under the combination of the high thermal load scenario and the dual-purpose

canister or disposable canister scenario (1.5 fatalities). The difference in fatalities is in part associated with the increased excavation activities and the larger operations area under the low thermal load.

In general, impacts from the high and intermediate thermal load scenarios would be about the same; those from the low thermal load scenario would be 8 to 10 percent higher. Similarly, impacts from the uncanistered packaging scenario would be 10 to 15 percent higher than for the dual-purpose and disposable canister scenarios. The differences in impacts reflect differences in the number of workers required for the scenarios.

Nonradiological Impacts to Workers and the Public. DOE would use engineering controls during subsurface work to control exposures of subsurface workers to silica dust that might contain cristobalite. If engineering controls could not keep dust concentrations below established limits, subsurface workers would have to wear respirators. Similar controls would be applied for surface workers if necessary. DOE expects that exposure of subsurface and surface workers to silica dust would be below applicable regulatory limits and that potential impacts to these workers would be low. Cristobalite concentrations at the site boundary would be small and unlikely to pose impacts to the public.

Radiological Impacts to Workers. Radiological impacts to workers are reported both in terms of the increase in likelihood of a latent cancer fatality for an individual, and the increase in the total number of latent cancer fatalities for the total worker population. DOE calculated a total increase of 3 to 4 potential latent cancer fatalities for repository workers during construction, operating and monitoring, and closure activities, depending on the thermal load. The probability of the maximally exposed worker incurring a latent cancer fatality would be small (between 0.006 and 0.008, or between 6 and 8 chances in 1,000) through the closure of the repository.

The highest estimated number of potential latent cancer fatalities to workers (4) would occur under the combination of the low thermal load scenario and the uncanistered packaging scenario. The lowest estimated number would occur under the combination of the high thermal load scenario and the dual-purpose canister or disposable-canister scenario (2.6 fatalities).

Radiological health impacts to workers would be greatest for the low thermal load scenario, about 20 percent higher than those for the high thermal load scenario because of the larger number of workers required. Worker impacts for the uncanistered scenario would be about one-third higher than those for the other packaging scenarios, again because of the larger number of workers required, and because of potential exposure to krypton-85 and carbon-14 gases.

The principal source of exposure to workers from radioactivity would be spent nuclear fuel receipt and handling activities in the surface facilities (about 50 percent). The other large contributor (about 25 percent) would be radiation exposure from the inhalation of radon-222 and the decay products by subsurface workers during construction and emplacement activities. Other important radiological contributions to worker health effects in the subsurface environment would come from naturally occurring radionuclides in the rock of the drifts.

Radiological Impacts to the Public. Short-term radiological health impacts to the public for Yucca Mountain construction, operation and monitoring, and closure would be small. (Impacts from transportation are discussed in Section S.4.2.) The likelihood that the maximally exposed individual would incur a latent cancer fatality from proposed repository activities would be less than 0.00002 (2 in 100,000) under the high thermal load scenario and about 0.00005 (5 in 100,000) under the low thermal load scenario. The estimated total number of latent cancer fatalities for the public through the closure of the repository would be less than one [ranging from 0.14 (high thermal load) to 0.41 (low thermal load)].

For the sake of comparison, the American Cancer Society reports that the Nevada cancer fatality rate per year from all sources is 185 deaths per 100,000 people. Assuming this mortality rate would remain

LATENT CANCER FATALITIES

A latent cancer fatality is a death from cancer resulting from, and occurring some time after, exposure to ionizing radiation. Exposure to radiation that results in a 1-rem (1,000-millirem) dose causes an estimated 0.0005 chance of causing a fatal cancer.

In a population of 10,000 people, national statistics indicate that about 2,224 people would die from cancer of one form or another. Using information developed by the International Commission on Radiological Protection, if all 10,000 people received a dose of 200 millirem (in addition to the normal background radiation dose), an estimated 1 additional cancer fatality would occur in that population. However, we would not be able to tell which of the 2,225 fatal cancers was caused by radiation and, possibly, the additional radiation would cause no fatal cancers.

Sometimes, calculations of the number of latent cancer fatalities associated with radiation exposure do not yield whole numbers, and, especially in environmental applications, may yield numbers less than 1.0. For example, if each individual in a population of 100,000 received a total dose of 0.001 rem, the collective dose would be 100 person-rem and the corresponding estimated number of latent cancer fatalities would be 0.05 (100,000 persons × 0.001 rem × 0.0005 latent cancer fatality per person-rem). How should one interpret a nonintegral number of latent cancer fatalities, such as 0.05? The answer is to interpret the result as a statistical estimate. That is, 0.05 is the *average* number of deaths that would result if the same exposure situation were applied to many different groups of 100,000 people. For most groups, no one would incur a latent cancer fatality from the 0.001 rem dose each member would have received. In a small fraction of the groups, 1 latent fatal cancer would result; in exceptionally few groups, 2 or more latent fatal cancers would occur. The *average* number of deaths over all of the groups would be 0.05 latent fatal cancer (just as the average of 0, 0, 0, and 1 is 1/4, or 0.25). The most likely outcome for any single group is 0 latent cancer fatalities.

unchanged over the 100-year period of repository construction, operation and monitoring, and closure, the population of about 28,000 within 80 kilometers (50 miles) of the Yucca Mountain site would experience an annual cancer mortality rate of about 50 cancer deaths per year from causes unrelated to the proposed repository at Yucca Mountain. Thus, through the closure of the repository, cancer deaths from other causes would total about 5,000.

Long-Term Radiological Health Impacts. DOE considered potential long-term human health impacts for 9,900 years after repository closure and also determined the peak dose rate during 1 million years after repository closure. The analysis estimated potential human health impacts from the undisturbed evolution of the repository, which would include such natural processes as corrosion of waste packages, dissolution of waste forms, and changing climate. In addition, it considered the effects of such disturbances as exploratory drilling or volcanic events.

The heat generated by spent nuclear fuel and high-level radioactive waste (the thermal load) could affect the long-term performance of the repository (that is, the ability of the engineered and natural barrier system to isolate the emplaced waste from the accessible environment for long periods).

UNCERTAINTY IN LONG-TERM PERFORMANCE

A substantial amount of uncertainty is associated with estimates of long-term repository performance. The uncertainty regarding a repository's long-term performance was handled in two ways. First, where the uncertainty was considered very important to the outcome, conservative assumptions were used that tended to overstate the risks that would be obtained by a more realistic model. Second, ranges of data were used in a probabilistic sampling routine to produce ranges of results that reflected the effect of the range of inputs. This ensures that the long-term performance estimates are conservative.

Different thermal loads would have different direct effects on internal and external waste package temperatures, potentially affecting the corrosion rate and integrity of the waste packages. In addition, the heat generated by the packages could affect the geochemistry, hydrology, and mechanical stability of the emplacement drifts, which in turn could influence groundwater flow and the transport of radionuclides from the engineered and natural barrier systems to the environment.

For all three thermal load scenarios, radioactive materials that entered the groundwater would produce the primary impacts from the repository to human health in the far future. Figure S-21 shows the potential movement of contaminants from the repository to the accessible environment. The analysis estimated human health impacts from the groundwater pathway at four locations in the Yucca Mountain region: water wells 5, 20, and 30 kilometers (3, 12, and 19 miles) from the repository and the nearest surface-water discharge point, which is about 80 kilometers (50 miles) away. The estimated health impact would be the probability of a resulting latent cancer fatality from lifetime use of the contaminated water.

Under all three thermal load scenarios, less than 1 latent cancer fatality would be likely over the 9,900-year analysis period. The analysis indicated that the high thermal load scenario would have a higher dose rate [1.3 millirem per year at 5 kilometers (3 miles)] and correspondingly greater health effects on the maximally exposed individual (lifetime probability of a latent fatal cancer of 0.000044) than the other scenarios. In addition, concentrations of chemically toxic materials were found to be lower than identified Maximum Contaminant Levels and Maximum Contaminant Level Goals and where no levels or goals have been established were found to be very low. Therefore, DOE does not anticipate detrimental impacts to water quality or human health from toxic materials.

In addition, DOE estimated the dose rate for 1 million years after repository closure. For the high thermal load scenario, the peak dose rate would be 9,100 millirem to a maximally exposed individual at 5 kilometers from the repository, occurring 320,000 years after closure (2,800 millirem under the intermediate thermal load scenario and 3,600 millirem under the low thermal load scenario). Variations in the peak dose rates to a maximally exposed individual among the three thermal loads would be caused by earlier waste package failures under the high thermal load, placement of waste packages in different areas of the repository, and different amounts of water infiltrating through the different repository areas.

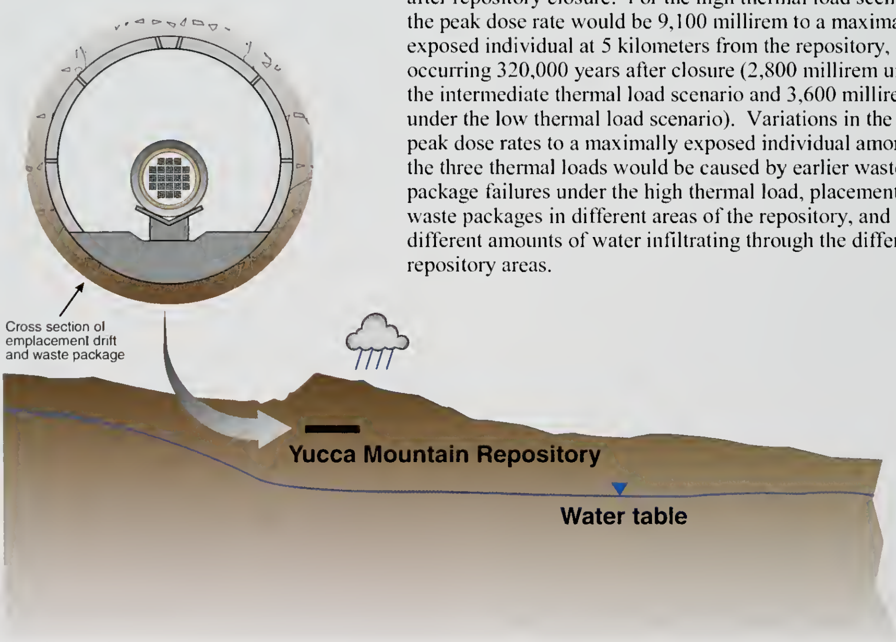


Figure S-21. Potential movement of contaminants from the repository to the accessible environment.

S.4.1.9 Accident Scenarios

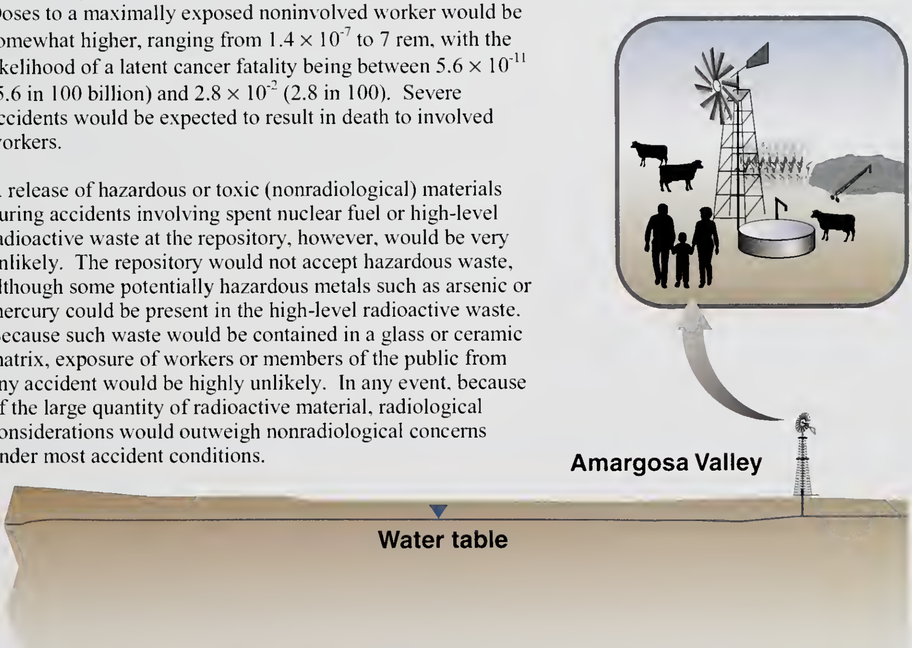
ACCIDENT

An unplanned event or sequence of events that results in undesirable consequences.

The evaluation of accident scenarios associated with the Proposed Action included the potential for radiological accidents and accidents involving exposure to hazardous and toxic substances in the first 100 years of repository activities. The potentially affected individuals considered include (1) the maximally exposed individual, a hypothetical member of the public at the point on the site boundary who would receive the largest dose, (2) the involved worker who would be handling the spent nuclear fuel or high-level radioactive waste when the accident occurred, (3) the noninvolved worker near the accident but not involved in handling the material, and (4) members of the public living within about 80 kilometers (50 miles) of the repository. The accident scenario analysis examined consequences under both median (50th-percentile) meteorological conditions and highly unfavorable meteorological conditions (95th-percentile, or those that would not be exceeded more than 5 percent of the time) that tend to maximize potential radiological impacts.

DOE analyzed 16 accident scenarios that represent all reasonably foreseeable impacts from accidents that could occur during repository operations. The frequency of these accident scenarios ranged from 0.59 per year to 1.2×10^{-7} per year. Impacts to the maximally exposed offsite individual from any of these accidents would be small, with doses ranging from 1.9×10^{-9} to 0.013 rem. The corresponding chance of a latent cancer fatality if such an accident occurred would be between 3.1×10^{-13} (3.1 in 10 trillion) and 1.6×10^{-5} (1.6 in 100,000) over the lifetime of the individual. Doses to a maximally exposed noninvolved worker would be somewhat higher, ranging from 1.4×10^{-7} to 7 rem, with the likelihood of a latent cancer fatality being between 5.6×10^{-11} (5.6 in 100 billion) and 2.8×10^{-2} (2.8 in 100). Severe accidents would be expected to result in death to involved workers.

A release of hazardous or toxic (nonradiological) materials during accidents involving spent nuclear fuel or high-level radioactive waste at the repository, however, would be very unlikely. The repository would not accept hazardous waste, although some potentially hazardous metals such as arsenic or mercury could be present in the high-level radioactive waste. Because such waste would be contained in a glass or ceramic matrix, exposure of workers or members of the public from any accident would be highly unlikely. In any event, because of the large quantity of radioactive material, radiological considerations would outweigh nonradiological concerns under most accident conditions.



S.4.1.10 Noise

Background noise at Yucca Mountain is caused by natural phenomena such as rain and wind and noise from people, including vehicles from site characterization activities and from occasional low-flying military jets. Sound-level measurements recorded in May 1997 at areas adjacent to and at the Yucca Mountain site were consistent with noise levels associated with industrial operations (sound levels from 43 to 72 decibels).

Repository activities during construction, operation, and closure that could generate elevated noise levels would include use of heavy equipment, ventilation fans, diesel generators, transformers, and a concrete batch plant.

Workers at the repository site could be exposed to elevated levels of noise. However, worker exposures to elevated noise levels during all repository phases would be controlled by the use of protective equipment, so impacts from noise would be unlikely.

The distance from the Yucca Mountain site to the nearest housing is about 22 kilometers (14 miles). Based on an estimated maximum noise level from repository operations, DOE calculated that noise from the repository would be at the lower limit of human hearing at 6 kilometers (3.7 miles). For this reason, DOE expects no meaningful noise impacts to the public from repository construction and operations.

S.4.1.11 Aesthetics

Yucca Mountain has visual characteristics fairly common to the region, and the visibility of the site from publicly accessible locations is low or nonexistent. The largest structure would be the Waste Handling Building at the North Portal Operations Area, which would be about 37 meters (120 feet) tall with a taller exhaust stack. Other buildings and structures would be smaller and at elevations equal to or lower than that of the Waste Handling Building. No building or structure would exceed the elevation of the southern ridge of Yucca Mountain [1,400 meters (4,500 feet)]. Therefore, no part of the repository would be visible to the public from the west. The intervening Striped Hills and the low elevation of the southern end of Yucca Mountain and Busted Butte would obscure the view of repository facilities from the south near Lathrop Wells and the Amargosa Valley, approximately 28 kilometers (17 miles) away. There is no public access to the north or east of the repository site to enable viewing of the facilities. DOE would provide lighting for operation areas at the repository that could be visible from public access points. Closure activities, such as dismantling facilities and reclaiming the site, would be likely to restore the visual quality of the landscape, as viewed from the site itself.

S.4.1.12 Utilities, Energy, and Materials

The scope of the analysis included electric power use, fossil-fuel consumption, consumption of construction materials, and onsite services such as emergency medical support, fire protection, and security and law enforcement. Overall, DOE does not expect large impacts to residential water, energy, materials, and emergency services from the Proposed Action.

Electricity. The repository demand for electricity would be well within the expected regional capacity for power generation. The current electric power supply line has a capacity of 10 megawatts. During the early stages of repository operations, when emplacement activities would be occurring while new drifts were being developed, the peak electric power demand would be between 34.5 and 37.5 megawatts, depending on the thermal load and packaging scenarios. Therefore, DOE could need to enhance the electric power delivery system to the Yucca Mountain site.

Fossil Fuel. Fossil fuel would include diesel fuel, gasoline, and fuel oil. During the construction phase, the low thermal load scenario and the uncanistered packaging scenario would require construction of

more facilities, thereby requiring the highest use of fossil fuels. Yearly repository use during construction would be less than 1 percent of the current use in Clark, Lincoln, and Nye Counties, and should result in only small impacts to fossil-fuel supplies.

Fossil-fuel use during the operation and monitoring phase would be highest during emplacement and development operations and would decrease substantially during monitoring and maintenance activities. The highest annual use would be less than 5 percent of the 1996 use in Clark, Lincoln, and Nye Counties. Thus, the projected use of liquid fossil fuels should be within the available regional capacity and should result in only small impacts to fossil-fuel supplies.

Construction Materials. The primary materials needed to build the repository would be concrete, steel, and copper. Concrete, which consists of cement and aggregate, would be used for subsurface tunnel liners and the construction of surface facilities. DOE would use excavated rock for aggregate, and would purchase cement regionally. The low thermal load scenario would require the largest amount of concrete, which would be less than 3 percent of the amount used in Nevada in 1997. Because steel and copper have worldwide markets, DOE expects little or no impact from an increased demand for steel and copper in the region.

Emergency Services. An emergency response system would be established to respond to accidents at the repository site. The capabilities would include emergency and rescue equipment, communications, facilities, and trained professionals to respond to fire, radiological, mining, industrial, and general accidents above or below ground. The onsite service capabilities would be able to respond to most events, including underground events, without outside support. Therefore, a large impact on the emergency services of surrounding communities or counties would be unlikely.

S.4.1.13 Waste Management

The evaluation of waste management impacts considered the quantities of nonhazardous industrial, sanitary, hazardous, mixed (both radioactive and hazardous), and radioactive wastes that repository-related activities would generate. DOE would build onsite facilities to accommodate construction and demolition debris, sanitary and industrial solid wastes, sanitary sewage, and industrial wastewater, or could use the existing Nevada Test Site landfill. DOE would use less than 3 percent of the existing available offsite capacity for low-level radioactive waste disposal and a smaller fraction of the available hazardous waste disposal capacity.

The different thermal load scenarios would produce different nonradioactive waste quantities due to the different workforce sizes. Similarly, the different waste packaging scenarios would affect the volumes of hazardous and low-level radioactive waste due to the differences in handling the spent nuclear fuel and high-level radioactive waste. However, the overall impact of managing the Yucca Mountain waste streams would not differ greatly among the thermal load and packaging scenarios.

RECYCLING OF DUAL-PURPOSE CANISTERS

The dual-purpose canister packaging scenario would involve the ultimate disposal of the canisters [that is, an additional estimated 30,000 cubic meters (1 million cubic feet) of low-level radioactive waste]. DOE could decide to recycle the canister materials if doing so would be more protective of the environment and more cost-effective than disposing of them.

S.4.1.14 Environmental Justice

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs Federal agencies to work to achieve "environmental justice" by

POPULATIONS

Minority: individuals who are American Indian or Alaskan Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic. For this EIS, a minority community is one in which the percent of the population of a racial or ethnic minority is 20 percentage points higher than the percent found in the population as a whole.

Low income: individuals with an income below the poverty level defined by the U.S. Bureau of the Census. A low-income population is one in which 25 percent or more of the persons in the population live in poverty.

identifying and addressing the potential for their activities to cause disproportionately high and adverse impacts to minority and low-income populations. As part of this process, DOE has identified the minority and low-income communities in Clark, Lincoln, and Nye Counties, using U.S. Bureau of the Census population designations to determine areas with high concentrations of minority or low-income populations.

DOE considered the potential for disproportionately high and adverse impacts to minority and low-income populations under both normal and accident conditions. The Department first analyzed the nature of the impacts on the population as a whole and concluded that the impacts would be low. The Department then considered whether any segment of the population, including minorities or low-income populations, would be affected disproportionately and concluded they would not. Accordingly, DOE believes that there would be no disproportionately high and adverse impacts to minority or low-income populations as a result of the Proposed Action. The Department, however, recognizes that Native American tribes in the region consider the intrusive nature of the repository and continuation of restrictions on access to lands where the repository would be located to have an adverse impact on all elements of the natural and physical environment and to their way of living within that environment.

S.4.1.15 Sabotage

Sabotage would be unlikely to contribute to impacts from the repository. The repository would not represent an attractive target to potential saboteurs due to its remote location and low population density in the area. Furthermore, security measures DOE would use to protect the waste material from intrusion and sabotage would make such attempts unlikely to succeed. At all times the waste material would be either in robust shipping or disposal containers or inside the Waste Handling Building, which would have thick concrete walls.

Under the Proposed Action, spent nuclear fuel and high-level radioactive waste would be permanently entombed in a sealed geologic repository at Yucca Mountain. Postdisposal access to the material by intruders would be extraordinarily difficult. Therefore, DOE believes that the risk of sabotage of materials for nuclear weapons purposes would be extremely remote.

S.4.2 TRANSPORTATION

The loading and shipping of spent nuclear fuel and high-level radioactive waste would take place at 72 commercial and 5 DOE sites. Legal-weight trucks and trains would travel on the Nation's highways and railroads. Barges and heavy-haul trucks would be used for the short-distance transport of spent nuclear fuel from some commercial sites to nearby railroads. Shipments of spent nuclear fuel and high-level radioactive waste arriving in Nevada would travel to the Yucca Mountain site by legal-weight truck, rail, or heavy-haul truck. Legal-weight truck shipments would use existing highways in accordance with U.S. Department of Transportation regulations. Figures 13 and 14 show the alternatives for rail corridors and intermodal transfer station locations and associated heavy-haul truck routes, respectively, in the State of Nevada.

DOE analyzed the impacts of transporting these materials to the repository under the mostly legal-weight truck and mostly rail scenarios. Under the mostly legal-weight truck scenario, most of the spent nuclear fuel and high-level radioactive waste would be shipped by legal-weight truck, while naval fuel would be shipped by rail. Under the mostly rail scenario, commercial spent nuclear fuel from most sites and DOE and naval spent nuclear fuel and high-level radioactive waste would arrive by rail. However, commercial fuel from a few commercial sites would be shipped by legal-weight truck because those sites do not have the capability to load a rail cask.

At present, there is no rail access to the Yucca Mountain site. If material was shipped by rail, a branch line that connected an existing main line to the Yucca Mountain site would have to be built or the material would have to be transferred to heavy-haul trucks at an intermodal transfer station and transported over existing highways that might need upgrading. DOE examined the environmental impacts that would be associated with a new branch rail line (five alternative rail corridors) and with an intermodal transfer station (three alternative locations) and heavy-haul routes (five alternative routes).

S.4.2.1 National Transportation Impacts

National transportation includes the impacts of transporting spent nuclear fuel and high-level radioactive waste from the commercial and DOE sites to the Yucca Mountain site. The differences in the impacts between the mostly legal-weight truck and mostly rail scenarios would result from the differing number of shipments over the 24-year transportation period. The mostly legal-weight truck scenario would involve about 49,800 cask shipments (49,500 truck shipments and 300 rail shipments), and the mostly rail scenario would involve approximately 13,400 cask shipments (10,800 rail shipments and 2,600 legal-weight truck shipments). Primarily because of the larger number of shipments, the mostly legal-weight truck scenario would have greater incident-free radiological impacts (latent cancer fatalities). The consequences of the maximum reasonably foreseeable transportation accident (an accident with the highest consequence for human health that can be reasonably foreseen) would be higher under the mostly rail scenario (31 latent cancer fatalities) than under the mostly legal-weight truck scenario (5 latent cancer fatalities) because the amount of material in a rail shipment would be larger than that in a legal-weight truck shipment.

ESTIMATED NATIONAL TRANSPORTATION IMPACTS
(for 24 years of operation)

Impact	Mostly legal-weight truck scenario	Mostly rail scenario
Incident-free latent cancer fatalities		
Involved worker	11	3
Public[a]	18	3
Latent cancer fatalities from accidents		
Public	0.07	0.02
Traffic fatalities	4	4
Latent cancer fatalities from maximum reasonably foreseeable accident	5	31
Frequency of occurrence per year	1.9×10^{-7}	1.4×10^{-7}

a. These latent cancer fatalities would result from very low doses to a very large population.

Under the Proposed Action, the analysis of transportation of spent nuclear fuel and high-level radioactive waste from the 72 commercial and 5 DOE sites considered the risk of sabotage. Sabotage could result in the release of radionuclides to the environment. The potential impacts from the release of radionuclides to the environment from an act of sabotage would be bounded by the potential impacts identified under the maximum reasonably foreseeable accident scenario.

S.4.2.2 Nevada Transportation Impacts

The analysis of national transportation includes the analysis of transportation activities in the State of Nevada. The EIS discusses Nevada transportation separately as well. Spent nuclear fuel and high-level radioactive waste shipped to the repository by legal-weight truck would continue in the same vehicles to the Yucca Mountain site. Material that traveled by rail would either continue to the repository on a newly constructed branch rail line or transfer to heavy-haul trucks at an intermodal transfer station that DOE would build in Nevada for shipment on existing highways that could require upgrades. Selection of a specific rail alignment within a corridor, or the specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul routes, would require additional field surveys, environmental and engineering analysis, state and local government consultation, and National Environmental Policy Act reviews.

Rail Corridor Implementing Alternatives. DOE assessed five rail implementing alternatives—the Caliente, Carlin, Caliente-Chalk Mountain, Jean, and Valley Modified corridors (see Figure S-13). The assessment considered the impacts of constructing a branch rail line in one of the five 400-meter (0.25-mile)-wide corridors. Each corridor would connect the Yucca Mountain site with an existing mainline railroad in Nevada.

Intermodal Transfer Station and Heavy-Haul Truck Route Implementing Alternative. DOE assessed alternative intermodal transfer station locations at rail terminals near Caliente, Apex/Dry Lake, and Sloan/Jean (see Figure S-14). The intermodal transfer station would transfer casks containing spent nuclear fuel and high-level radioactive waste from railcars to heavy-haul trucks and empty casks from heavy-haul trucks to railcars. In addition, DOE assessed three alternative heavy-haul truck routes from a Caliente intermodal transfer station – Caliente, Caliente-Chalk Mountain, and Caliente-Las Vegas—and one route each from the Apex/Dry Lake and Sloan/Jean locations. This implementing alternative probably would include about 110 legal-weight truck shipments of commercial spent nuclear fuel each year from the 9 sites that do not currently have the capability to load rail casks.

Impacts for any of the five alternative rail corridors or five heavy-haul truck routes over the 24 years of transport operations would include the following:

- The incident-free collective dose to members of the public would result in less than 1 latent cancer fatality.
- The cumulative radiological accident risk would be much less than 1 latent cancer fatality, taking into account both the probability of accident occurrence and the resulting consequences if an accident were to occur.
- The likelihood of the maximum reasonably foreseeable accident in an urbanized area is about 1.5 to 2 chances in 10 million per year; if such an accident were to occur, from 5 to 31 latent cancer fatalities could result.
- From 1 to 4 traffic fatalities would be likely to occur due to traffic accidents.
- The amount of land disturbed (for an intermodal transfer station and mid-route stops) would be small, generally less than 0.3 square kilometer (75 acres).
- Impacts to biological resources due to habitat disturbance and loss of individuals of affected species would be small.
- Based on an assessment, potential impacts from activities in floodplains and wetlands would be small.

RAIL CORRIDOR IMPACTS

Caliente
- 513 kilometers (319 miles) long, requiring 1 day to complete a one-way trip.
- Would disturb 18 square kilometers (4,500 acres) of land.
- 1,200 new jobs (primary and secondary) could be created during 2.5 years of construction.
- Estimated life-cycle cost is $801 million (1997 dollars).

Carlin
- 520 kilometers (323 miles) long, requiring 1 day to complete a one-way trip.
- Would disturb 20 square kilometers (4,900 acres) of land.
- 1,100 new jobs (primary and secondary) could be created during 2.5 years of construction.
- Estimated life-cycle cost is $753 million (1997 dollars).

Caliente-Chalk Mountain
- 345 kilometers (214 miles) long, requiring less than 1 day to complete a one-way trip.
- Would disturb 12 square kilometers (3,000 acres) of land.
- 910 new jobs (primary and secondary) could be created during 2.5 years of construction.
- Estimated life-cycle cost is $566 million (1997 dollars).
- Nonpreferred alternative: Strongly opposed by the U.S. Air Force because of the adverse effect on security and operations at Nellis Air Force Range.

Jean
- 181 kilometers (112 miles) long, requiring 3-4 hours to complete a one-way trip.
- Would disturb 9 square kilometers (2,000 acres) of land.
- 720 new jobs (primary and secondary) could be created during 2.5 years of construction.
- Estimated life-cycle cost is $421 million (1997 dollars).
- Other: Could affect scenic quality lands and habitat for desert tortoise; would pass near the Las Vegas metropolitan area.

Valley Modified
- 159 kilometers (98 miles) long, requiring 3 hours to complete a one-way trip.
- Would disturb 5 square kilometers (1,240 acres) of land.
- 350 new jobs (primary and secondary) could be created during 2.5 years of construction.
- Estimated life-cycle cost is $258 million (1997 dollars).
- Other: Could affect Desert National Wildlife Range on Nellis Air Force Range, would pass near Las Vegas Paiute Indian Reservation; would pass near the Las Vegas metropolitan area.

- There could be small visual impacts from the existence of the branch rail line, access road, and borrow pits in the landscape and the passage of trains to and from the repository along any rail corridor.

- There would be no effect on the general availability of gasoline, diesel fuel, steel, or concrete.

- There would be no disproportionately high and adverse impacts to minority and low-income populations. DOE considered impacts that would be associated with potential routes for rail and legal-weight and heavy-haul trucks that would pass through or near the Moapa and Las Vegas Paiute Indian Reservations.

HEAVY-HAUL ROUTE IMPACTS

Caliente
- 533 kilometers (331 miles) long, requiring 2 days to complete a one-way trip.
- 1,000 new jobs (primary and secondary) could be created during 3 years of construction.
- Estimated life-cycle cost is $619 million (1998 dollars).
- Other: Could have visual impacts to Kershaw-Ryan State Park.

Caliente-Chalk Mountain
- 282 kilometers (175 miles) long, requiring 2 days to complete a one-way trip.
- 830 new jobs (primary and secondary) could be created during 2.2 years of construction.
- Estimated life-cycle cost is $507 million (1998 dollars).
- Nonpreferred alternative: Strongly opposed by the U.S. Air Force because of the adverse effect on security and operations at the Nellis Air Force Range.
- Could have visual impacts to Kershaw-Ryan State Park.

Caliente-Las Vegas
- 377 kilometers (234 miles) long, requiring 2 days to complete a one-way trip.
- 810 new jobs (primary and secondary) could be created during 2.1 years of construction.
- Estimated life-cycle cost is $561 million (1998 dollars).
- Other: Could have visual impacts to Kershaw-Ryan State Park and would pass near the Las Vegas metropolitan area; would pass near the Moapa Indian Reservation and through the Las Vegas Paiute Indian Reservation.

Apex/Dry Lake
- 183 kilometers (114 miles) long, requiring one-half day to complete a one-way trip.
- 540 new jobs (primary and secondary) could be created during 0.5 year of construction.
- Estimated life-cycle cost is $358 million (1998 dollars).
- Other: Would pass near the Las Vegas metropolitan area; could pass near the Moapa Indian Reservation and through the Las Vegas Paiute Indian Reservation.

Sloan/Jean
- 188 kilometers (117 miles) long, requiring one-half day to complete a one-way trip.
- 720 new jobs (primary and secondary) could be created during 0.5 year of construction.
- Estimated life-cycle cost is $411 million (1998 dollars).
- Other: Would pass near the Las Vegas metropolitan area; would pass through the Las Vegas Paiute Indian Reservation.

The factors that differ among the alternative transportation corridors and routes are length and associated time of travel, land use or disturbance, industrial safety impacts, job creation, and cost. The U.S. Air Force has informed DOE that it strongly opposes the Caliente-Chalk Mountain corridor because it could adversely affect national security-related activities of the Nellis Air Force Range. The State of Nevada and the City of Las Vegas have expressed specific concerns about shipments through or near the Las Vegas metropolitan area, which would occur if either the Jean or Valley Modified corridor or the Caliente-Las Vegas, Apex/Dry Lake, or Sloan/Jean heavy-haul route was selected.

S.5 Environmental Consequences of the No-Action Alternative

Under the No-Action Alternative, DOE would terminate site characterization activities at the Yucca Mountain site. Long-term storage of spent nuclear fuel and high-level radioactive waste would continue at 77 sites.

DOE analyzed the potential impacts of two no-action scenarios: long-term storage with institutional controls (Scenario 1) and long-term storage with no effective institutional control after about 100 years (Scenario 2). The Department recognizes that neither of these scenarios is likely to occur if there is a decision not to develop a repository at Yucca Mountain, but any other scenarios would be too speculative for meaningful analysis. DOE therefore chose to include the two scenarios because they provide a baseline for comparison to the impacts from the Proposed Action.

Activities at the Yucca Mountain site would be the same under either Scenario 1 or 2, as would impacts at the commercial and DOE sites during the first 100 years. After about 100 years and for as long as the 10,000-year analysis period and beyond, Scenario 2 assumes that the storage facilities at the 72 commercial sites and 5 DOE sites would deteriorate and that the radioactive materials in the spent nuclear fuel and high-level radioactive waste would eventually escape to the environment, contaminating the atmosphere, soil, surface water, and groundwater.

S.5.1 RECLAMATION AND DECOMMISSIONING AT THE YUCCA MOUNTAIN SITE

Under the No-Action Alternative, DOE would end characterization and construction activities at the Yucca Mountain Repository site and would complete site decommissioning and reclamation. Land ownership and control would revert to the original controlling authority. Adverse impacts to any resource would be unlikely as a result of these activities.

The overall impact of the No-Action Alternative would be the loss of approximately 4,700 jobs in the Yucca Mountain region of influence, out of approximately 870,000 jobs in the region. Most of the lost jobs would be in disciplines (construction, engineering, administration, support, etc.) that are not unique or unusual and are similar to those in the region. However, some of the jobs would be in unique disciplines (nuclear engineering, nuclear safety, etc.) and might not be needed in the region. Fatalities from industrial hazards would be unlikely, as would latent cancer fatalities from worker or public exposure to naturally occurring radionuclides released by decommissioning and reclamation activities. Resources important to Native American interests would be preserved, although the integrity of archeological sites and resources could be threatened by increased public access if roads were open and site boundaries were not secure.

S.5.2 CONTINUED STORAGE AT COMMERCIAL AND DOE SITES

The No-Action Alternative assumes that the spent nuclear fuel and high-level radioactive waste would remain at the sites at which it is being generated and stored. For the EIS analysis, DOE divided the 72 commercial and 5 DOE sites among five regions of the country to organize the analysis into a framework that would promote an understanding of comparative impacts, and configured a single hypothetical site in each region. Such sites do not exist but are mathematical constructs for analytical purposes. Using this approach, DOE was able to estimate the potential release rate of the radionuclide inventory from the spent nuclear fuel and high-level radioactive waste, based on anticipated interactions of the environment (for example, rainfall and freeze-thaw cycles) with the concrete storage modules in which the nuclear materials would be stored.

The potential occupational and public health and safety impacts associated with the No-Action Alternative are described below. For purposes of this analysis, the potential occupational and public health and safety impacts are the most relevant for comparison with the impacts of the Proposed Action.

S.5.2.1 No-Action Scenario 1

Under this scenario, releases of contaminants to the ground, air, or water would be extremely small under normal conditions. Workers would perform routine industrial maintenance and maintenance unique to a nuclear materials storage facility to minimize releases of contaminants to the environment and exposures

IMPACTS FROM NO-ACTION SCENARIO 1

Industrial hazards

- 2 worker fatalities in the first 100 years, and 320 in the next 9,900 years

Radiological

- 3.0 latent cancer fatalities in exposed public population over 10,000 years (compared to 3.3 million from other causes in the areas immediately surrounding the 77 sites)
- 13 latent cancer fatalities in worker population over 10,000 years (compared to 37,600 from other causes)
- 15 latent cancer fatalities in noninvolved worker population over 100 years, after which noninvolved workers would not be present at the site (compared to 18,800 from other causes)
- No radiological releases would be expected in the event of a severe accident (a postulated aircraft crash) because of the integrity of the concrete storage modules.

to workers and the public. These activities could result in worker exposures to industrial hazards, and worker and public exposures to radiological releases.

S.5.2.2 No-Action Scenario 2

Under this scenario, after 100 years the facilities storing the materials at 72 commercial and 5 DOE sites would begin to deteriorate and would continue to do so over time. Eventually, radioactive materials from failed facilities and storage containers and exposed radioactive materials would contaminate the land surrounding the storage facilities, potentially rendering it unfit for human habitation or agricultural uses for hundreds or thousands of years. Contaminants would enter surface waters and groundwater, which would remain contaminated for the period required for the spent nuclear fuel and high-level radioactive waste materials to be depleted and contaminants to migrate out. Environmental concentrations of chemically toxic materials would be extremely low and would not result in adverse impacts. Released radioactive materials could produce chronic radiation exposures to the public, which could result in adverse health impacts. Intruders could incur severe radiation exposures, including fatal exposures. The number of people who would be affected by the migration of radioactive materials would be much greater in Scenario 2 than in Scenario 1.

IMPACTS FROM NO-ACTION SCENARIO 2

Industrial hazards

- 2 worker fatalities in the first 100 years and none in the next 9,900 years (workers not present at the site)

Radiological

- 3,300 latent cancer fatalities in exposed public population over 10,000 years (compared to 900 million expected from other causes along the 20 major waterways that would be contaminated)
- No latent cancer fatalities in worker population after 100 years
- No latent cancer fatalities in noninvolved worker population after 100 years
- Depending on the population at the site, between 3 and 13 latent cancer fatalities would be expected in the event of a severe accident (a postulated aircraft crash) at a degraded concrete storage module

S.5.2.3 Sabotage

Under the No-Action Alternative, the storage of spent nuclear fuel and high-level radioactive waste at 72 commercial and 5 DOE sites would include a risk of intruder access. Sabotage at one of these sites could result in the release of radionuclides to the environment, or intruders could attempt to remove fissile material for use in weapons production.

For No-Action Scenario 1, the analysis assumed that safeguards and security measures would remain in effect for 10,000 years to minimize potential risks from intruders. For Scenario 2, the analysis assumed that such measures would not remain in effect after 100 years.

S.6 Cumulative Impacts of the Proposed Action

DOE evaluated cumulative short-term impacts from the construction, operation and monitoring, and closure of a geologic repository at Yucca Mountain, and cumulative long-term impacts after repository closure. It also evaluated cumulative impacts from the transportation of spent nuclear fuel and high-level radioactive waste to the repository, including those from the construction and operation of a branch rail line or of an intermodal transfer station and highway upgrades for heavy-haul trucks.

> **CUMULATIVE IMPACTS**
>
> A cumulative impact is "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (Council on Environmental Quality Regulations, 40 CFR 1508.7). Cumulative impacts can result from individually minor but collectively potentially significant actions that occur over time.

An assessment of the environment around the Yucca Mountain site included the cumulative impacts of past and present actions in the area the Proposed Action would affect. Reasonably foreseeable future actions include the disposal of inventories of spent nuclear fuel and high-level radioactive waste that exceed the Proposed Action inventory of 70,000 MTHM, along with other Federal and non-Federal actions at the Nellis Air Force Range and the Nevada Test Site, DOE waste management activities, a private space launch facility, and a private intermodal transfer station.

DOE could not reasonably predict future actions for the indefinite future. For that reason, DOE did not attempt to estimate cumulative impacts beyond about 100 years with the exception of impacts of radioactive materials reaching the groundwater and resulting in potential impacts to the public.

S.6.1 INVENTORY MODULES 1 AND 2

Comments that DOE received from the public during the scoping process for this EIS expressed the concern that more spent nuclear fuel and high-level radioactive waste would be generated than the 70,000 MTHM accounted for in the Proposed Action. In response to these comments, DOE evaluated the emplacement of the total projected inventory of commercial spent nuclear fuel and DOE spent nuclear fuel and high-level radioactive waste (Inventory Module 1) and of that total inventory plus the inventories of commercial Greater-Than-Class-C waste and DOE Special-Performance-Assessment-Required waste (Inventory Module 2).

The emplacement of Inventory Module 1 or 2 at Yucca Mountain would require legislative action by Congress unless a second repository were in operation. In addition, the emplacement of commercial Greater-Than-Class-C and DOE Special-Performance-Assessment-Required wastes could require either legislative action or a determination by the Nuclear Regulatory Commission to classify these materials as high-level radioactive waste.

INVENTORIES

Proposed Action
- 63,000 MTHM of commercial spent nuclear fuel
- 2,333 MTHM of DOE spent nuclear fuel
- 8,315 canisters of DOE high-level radioactive waste (equivalent of 4,667 MTHM)

Inventory Module 1
- 105,000 MTHM of commercial spent nuclear fuel
- 2,500 MTHM of DOE spent nuclear fuel
- 22,280 canisters of DOE high-level radioactive waste (equivalent of about 11,500 MTHM)

Inventory Module 2
- 105,000 MTHM of commercial spent nuclear fuel
- 2,500 MTHM of DOE spent nuclear fuel
- 22,280 canisters of DOE high-level radioactive waste (equivalent of about 11,500 MTHM)
- 2,100 cubic meters (72,500 cubic feet) of Greater-Than-Class-C waste
- 4,000 cubic meters (142,000 cubic feet) of Special-Performance-Assessment-Required waste

The emplacement of Inventory Module 1 or 2 would increase the size of the subsurface repository facilities and, thus, the amount of land disturbed. In addition, because more time would be required to emplace more materials (an additional 14 years for emplacement and perhaps another 10 years for closure under the low thermal load scenario) emplacement of Inventory Module 1 or 2 would produce greater human health impacts to workers and to the public, increase energy use, create larger amounts of waste, and increase transportation impacts. Although such impacts would increase by as much as 70 percent with the emplacement of larger waste volumes, most of the impacts themselves would be small. The following paragraphs focus on occupational and public health and safety impacts related to the disposal of the additional inventories.

ESTIMATED NATIONAL TRANSPORTATION IMPACTS
INVENTORY MODULE 1 OR 2
(for 38 years of operation)[a]

Impact	Mostly legal-weight truck scenario	Mostly rail scenario
Incident-free latent cancer fatalities		
Involved worker	19	5.5
Public[b]	31	4
Latent cancer fatalities from accidents		
Public	0.1	0.04
Traffic fatalities[c]	7	6.2
Latent cancer fatalities from maximum reasonably foreseeable accident	5	31
Frequency of occurrence per year	2.0×10^{-7}	1.6×10^{-7}

a. Modules 1 and 2 involve approximately the same number of shipments.
b. Potential latent cancer fatalities result from very small doses to a very large population.
c. Does not include 12.9 fatalities that could occur from repository workers commuting and transporting construction materials to the repository.

Occupational and Public Health and Safety

Impacts to Workers from Industrial Hazards. Two activities during the operation and monitoring phase – surface facility operations and the development of emplacement drifts – would account for more than 80 percent of the health and safety impacts from industrial hazards. Up to 3 fatalities under Module

1 or 2 could occur under the low thermal load and uncanistered packaging scenarios, compared to about 2 during the Proposed Action the first 100 years of repository operations.

Radiological Impacts to Workers. The principal sources of exposure to workers would be from spent nuclear fuel receipt and handling in the surface facilities and emplacement activities in the subsurface facilities. As many as approximately 6 fatalities under Module 1 or 2 could occur in the worker population under the intermediate thermal load and uncanistered fuel scenarios, compared to approximately 4 under the Proposed Action.

Radiological Impacts to the Public. Radiological health impacts to the public from construction, operation and monitoring, and closure of the repository would be small. The calculated likelihood that the maximally exposed individual would experience a latent cancer fatality is 3×10^{-5} or less under Module 1 or 2, compared to a range of 2.3×10^{-5} under the high thermal load scenario to 5×10^{-5} under the low thermal load scenario for the Proposed Action. Therefore, the estimated number of latent cancer fatalities would be less than 1 under either module, as it would be under the Proposed Action.

Long-Term Radiological Impacts. Long-term cumulative impacts (impacts after closure at the repository) to public health would occur from radionuclides ultimately from Yucca Mountain, past weapons testing on the Nevada Test Site, and past, present, and future disposal of radioactive waste on the Nevada Test Site and near Beatty, Nevada. Cumulative impacts over 10,000 years from radionuclides released to groundwater would result in less than about 0.003 latent cancer fatality over 10,000 years.

S.6.2 OTHER FEDERAL AND NON-FEDERAL ACTIONS

This EIS evaluates the potential cumulative impacts of other Federal and non-Federal actions. The evaluation includes activities by local governments, private citizens, the Nellis Air Force Range, the Bureau of Land Management, the National Park Service, and the Nevada Test Site. It shows that earlier underground nuclear testing potentially results in long-term (more than 10,000 years) cumulative impacts. Using conservative assumptions, the evaluation calculated the maximum potential dose from the radionuclides from underground testing to be 0.2 millirem per year. Therefore, the maximum cumulative impact of the Proposed Action in 10,000 years [using the mean impact at 20 kilometers (12 miles) from the repository] would be 0.22 millirem per year (potential Yucca Mountain Repository impact) plus 0.2 millirem per year (potential underground testing impact), or 0.42 millirem per year.

S.6.3 TRANSPORTATION

The shipment of Inventory Module 1 or 2 to the repository would use the transportation routes described for the Proposed Action but would require almost twice as many shipments and an additional 14 years. This could result in increased industrial hazards and latent cancer fatalities. For example, under the mostly legal-weight truck scenario, radiological and vehicle emission impacts from incident-free national transportation could increase from 11 to 14 occupational latent cancer fatalities, and estimated latent cancer fatalities in the general population could increase from 18 to 31 for the 38-year transportation of Inventory Module 1 or 2. The incident-free impacts of the mostly rail scenario could be smaller because there would be fewer shipments.

The implementation of the Proposed Action, together with past, present, and reasonably foreseeable future transportation of radioactive materials, could result in 140 latent cancer fatalities in the worker population and 170 in the general population under the mostly legal-weight truck scenario. Transportation of Inventory Module 1 or 2, together with past, present, and reasonably foreseeable future transportation of radioactive materials, could result in about 154 latent cancer fatalities (up to about 14 latent cancer fatalities from Module 1 or 2 plus 140 latent cancer fatalities) in the worker population and, about 200 (up to about 31 latent cancer fatalities from Module 1 or 2 plus 170 latent cancer fatalities) in the general population under the mostly legal-weight truck scenario.

S.7 Cumulative Impacts of the No-Action Alternative

DOE analyzed the cumulative impacts of the No-Action Alternative with respect to Inventory Module 1. The Department did not analyze the cumulative impacts of the No-Action Alternative with respect to Inventory Module 2 because it did not have sufficient and readily available information about the Greater-Than-Class-C and Special-Performance-Assessment-Required wastes in that module to perform a meaningful analysis. Furthermore, this information could not be obtained without an exorbitant commitment of resources. However, information was sufficient to make the determination that there would be a small incremental increase in impacts over those of Module 1.

DOE estimated that about 6,400 concrete storage modules at the 72 commercial sites and three below-grade vaults at the DOE sites would be required to store 70,000 MTHM of spent nuclear fuel and high-level radioactive waste. In comparison, an additional 4,600 concrete storage modules (11,000 total) at the commercial sites and an additional five below-grade vaults (eight total) at the DOE sites would be required to store the entire inventory of Module 1.

Impacts to Workers from Industrial Hazards. As many as 3 fatalities could occur at the storage and generator sites during the first 100 years under the No-Action Alternative with Inventory Module 1. This compares to 2 worker fatalities during the first 100 years with the 70,000-MTHM inventory. Over the next 9,900 years, approximately 490 fatalities could occur under No-Action Scenario 1 with Inventory Module 1, in comparison to 320 with the 70,000-MTHM inventory. No industrial hazard fatalities are projected for either the 70,000-MTHM inventory or Inventory Module 1 under No-Action Scenario 2 after the first 100 years because that scenario assumes there would be no workers at the sites.

Radiological Impacts to Workers. Approximately 43 latent cancer fatalities could occur at the storage and generator sites as a result of No-Action Scenario 1 with Inventory Module 1 over 10,000 years. This compares to 28 latent cancer fatalities in the worker population with the 70,000-MTHM inventory.

As with the 70,000-MTHM inventory, no latent cancer fatalities are projected in the worker population for Inventory Module 1 under No-Action Scenario 2 after 100 years because there would be no workers at the sites.

Radiological Impacts to the Public. About 5 latent cancer fatalities could occur in the exposed population over 10,000 years as a result of No-Action Scenario 1 with Inventory Module 1. This compares to about 4 latent cancer fatalities with the 70,000-MTHM inventory.

Under No-Action Scenario 2, the number of latent cancer fatalities could increase from about 3,300 in the exposed population with the 70,000-MTHM inventory over 10,000 years to about 3,700 in the same period with Inventory Module 1.

S.8 Management Actions to Mitigate Potential Adverse Environmental Impacts

DOE has identified the types of mitigation measures it could take to reduce or avoid potential adverse impacts from construction, operation and monitoring, and closure of the proposed repository. The type of actions identified to date include:

- Commitments included as part of the Proposed Action that would reduce impacts. These commitments are based on DOE's studies of Yucca Mountain that have been ongoing for more than 10 years.

- Actions that are under consideration in the event the U.S. Nuclear Regulatory Commission grants a license for the site. DOE would continue to evaluate these additional commitments. The analyses in the EIS do not take credit for these mitigations that may be decided on in the future.

In addition, DOE continues to evaluate whether to commit to additional measures to improve the long-term performance of the repository and to reduce uncertainties in estimates of performance. These mitigations include barriers to limit releases and transport of radionuclides, measures to control heat and moisture in the underground, and various designs to support operational considerations.

S.9 Unavoidable Adverse Impacts; Short-Term Uses and Long-Term Productivity; and Irreversible or Irretrievable Commitments of Resources

The construction, operation and monitoring, and eventual closure of the proposed Yucca Mountain Repository and the associated transportation of spent nuclear fuel and high-level radioactive waste would have the potential to produce some environmental impacts that DOE could not mitigate. Similarly, some aspects of the Proposed Action could affect the long-term productivity of the environment or would require the permanent use of some resources. For example:

- The permanent withdrawal of approximately 600 square kilometers (230 square miles) of land for the repository would be likely to prevent human use of the withdrawn lands for other purposes.

- Groundwater contamination could cause an attendant loss of productivity for the affected groundwater.

- Death or displacement of individual members of some animal species, including the desert tortoise, as a result of site clearing and vehicle traffic would be unavoidable.

- Injuries to workers or worker fatalities could result from facility construction, including accidents and inhalation of cristobalite.

- Transportation of spent nuclear fuel and high-level radioactive waste would have the potential to affect workers and the public through exposure to radiation and vehicle emissions, and through traffic accidents.

Further, in the view of the Native American tribes in the Yucca Mountain region, the implementation of the proposed repository and its facilities would further degrade the environmental setting. Even after closure and reclamation, the presence of the repository would, from the perspective of Native Americans, result in an irreversible impact to traditional lands.

In addition, the Proposed Action would involve the following commitments of resources:

- Electric power, fossil fuels, and construction materials would be irreversibly committed to the project.

- DOE would use fossil fuel from the nationwide supply system to transport spent nuclear fuel and high-level radioactive waste to the repository.

S.10 Statutory and Other Applicable Requirements

Several statutes and regulations would apply to the licensing, development, operation, and closure of a geologic repository. These include the NWPA; the National Environmental Policy Act; the Atomic

Energy Act; and the Federal Land Policy and Management Act of 1976. DOE is also subject to environmental protection requirements such as those set by the Clean Air Act; Clean Water Act; Hazardous Material Transportation Act; Emergency Planning and Community Right-to-Know Act of 1986; Comprehensive Environmental Response, Compensation, and Liability Act; Resource Conservation and Recovery Act; National Historic Preservation Act; Archaeological Resources Protection Act; Endangered Species Act; and applicable Nevada State statutes and regulations. In accordance with several statutes, DOE would need several new permits, licenses, and approvals from both Federal and State agencies to construct, operate and monitor, and eventually close the proposed Yucca Mountain Repository.

Under the authority of the Atomic Energy Act, DOE is responsible for establishing a comprehensive health, safety, and environmental program for its activities and facilities. The Department has established a framework for managing its facilities through the promulgation of regulations and the issuance of DOE Orders. In general, DOE Orders set forth policies, programs, and procedures for implementing policies. Many DOE Orders contain specific requirements in the areas of radiation protection, nuclear safety and safeguards, and security of nuclear material. Because the Nuclear Regulatory Commission is authorized to license the proposed Yucca Mountain repository, DOE issued Order 250.1 exempting such a repository from compliance with provisions of DOE Orders that overlap or duplicate Nuclear Regulatory Commission licensing requirements.

DOE has interacted with agencies authorized to issue permits, licenses, and other regulatory approvals, as well as those responsible for protecting such significant resources as endangered species, wetlands, or historic properties. DOE also has coordinated with the affected units of local government, U.S. Nuclear Regulatory Commission, U.S. Air Force, U.S. Navy, U.S. Department of Agriculture, U.S. Department of Transportation, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, National Park Service, Bureau of Land Management, Nevada Department of Transportation, and Native American tribes. In addition, DOE will provide a copy of the Draft EIS to these agencies and entities.

S.11 Findings

S.11.1 MAJOR FINDINGS OF THE EIS

In general, the Proposed Action would cause small, short-term public health impacts due primarily to the transportation of spent nuclear fuel and high-level radioactive waste from the existing commercial and DOE sites to the proposed repository. These impacts would be associated mainly with very low, nonradiological traffic fatalities and radiological doses to members of the public from the routine transportation of radioactive materials. Further, the EIS analysis demonstrated that the long-term performance of the proposed repository over 10,000 years would result in a peak dose of 1.3 millirem per year to a maximally exposed individual hypothetically located 5 kilometers (3 miles) from the repository.

Under the No-Action Alternative, there could be as many as 2 worker fatalities as a result of industrial hazards in the short term. Latent cancer fatalities would be unlikely in the short term in either the worker or public populations. These short-term impacts would be very similar to those associated with the Proposed Action. In addition, under the No-Action Alternative there would be no impacts associated with the transportation of spent nuclear fuel and high-level radioactive waste to the proposed repository. However, the obligation to store these materials continually in a safe configuration would become the responsibility of future generations.

There could be large public health and environmental consequences under the No-Action Alternative if there were no effective institutional control, causing storage facilities and containers to deteriorate and radioactive contaminants from the spent nuclear fuel and high-level radioactive waste to enter the environment. In such circumstances, there would be widespread contamination at the 72 commercial and 5 DOE sites across the United States, with resulting human health impacts.

Table S-1 compares the potential impacts associated with the Proposed Action to those associated with the No-Action Alternative.

S.11.2 AREAS OF CONTROVERSY

Native American tribes in the Yucca Mountain region value the cultural resources in the region and believe that the region's water, animals, plants, air, geology, and artifacts are interrelated and dependent on each other for existence. For this reason, these Native Americans consider the intrusive nature of the repository to be an adverse impact to all elements of the natural and physical environment. In addition, one Native American ethnic group, the Western Shoshone, continue to claim title to land in Nevada, including the Yucca Mountain site.

DOE obtained and evaluated the best information available to prepare this EIS. However, some information is from ongoing studies (such as the chlorine-36 studies used to assess the rate and quantity of water that flows from the surface to the groundwater) and, therefore, is incomplete or unavailable. Similarly, the interpretation of results might differ among researchers, or the use of different analytical methods might produce different results or conclusions (such as the variation in the depth to the water table over time, and perspectives of resource use and impacts held by Native American groups). In addition, the complexity and variability of the natural system at Yucca Mountain, the long periods evaluated, and the lack of completeness and availability of information have resulted in a degree of uncertainty associated with the results of the impact analyses (such as changes in climate, populations, society, and technology over very long periods). The EIS identifies the use of incomplete information and the unavailability of information, different views of results and conclusions, and the uncertainties associated with analysis results. In addition, the EIS describes the relevance and importance of the incomplete or unavailable information and then describes the assumptions and preliminary information used in the analysis. DOE has done this to help the reader understand the results or conclusions and their context.

S.11.3 DISTINCTIONS BETWEEN IMPACTS OF THE PROPOSED ACTION AND NO-ACTION ALTERNATIVE

The analysis of the potential short-term environmental impacts associated with the Proposed Action and with the two No-Action scenarios revealed that the impacts would be small and related to health and safety and to socioeconomics.

There would be about 22 to 50 latent cancer fatalities and nonradiological fatalities during the construction, operation and monitoring, and closure of a repository at Yucca Mountain (about 100 years). In comparison, there would be about 25 latent cancer fatalities and nonradiological fatalities from the No-Action Alternative (both scenarios) during the first 100 years. Transportation under the Proposed Action would result in about 6 to 28 latent cancer fatalities (depending on packaging and transportation scenario) and about 13 to 18 nonradiological fatalities from commuting, shipping construction materials, and shipping spent nuclear fuel and high-level radioactive waste to the repository. Under the No-Action Alternative (both scenarios), there would be no latent cancer fatalities from transportation and about 7 nonradiological fatalities from commuting and shipping construction materials. Under the Proposed Action, there would be about 3 to 4 latent cancer fatalities and 2 nonradiological fatalities during construction and operations. Under the No-Action Alternative (both scenarios) there would be about 16 latent cancer fatalities and 2 nonradiological fatalities during construction and operations.

Short-term socioeconomic impacts would occur in the Yucca Mountain region and at the existing storage locations under the Proposed Action; impacts under the No-Action Alternative would occur only in the Yucca Mountain region. Under the Proposed Action, there would be as many as about 2,400 new jobs in the three-county area around Yucca Mountain (Clark, Lincoln, and Nye Counties). In addition, under the Proposed Action there would be lost jobs at each of the sites across the United States as spent nuclear fuel

Table S-1. Impacts associated with the Proposed Action and No-Action Alternative (page 1 of 4).

	Proposed Action			No-Action Alternative		
	Short-term (through closure, about 100 years)		Long-term (after closure, about 100 to 10,000 years)	Short-term	Long-term (100 to 10,000 years)	
Resource area	Repository	Transportation		(100 years)	Scenario 1	Scenario 2
Land use and ownership	Withdraw about 600 km^2[a] of land now under Federal control; active use of about 3.5 km^2	0 to about 20 km^2 of land disturbed for new transportation routes; Air Force identified conflicts for some routes; Valley Modified rail corridor would pass near the Las Vegas Paiute Indian Reservation; some rail corridors could overlap with potential Las Vegas growth; heavy-haul trucks could slow traffic flow; some heavy-haul routes would pass near or through the Moapa and Las Vegas Paiute Indian Reservations	Potential for limited access into the area; the only surface features remaining would be markers	Small; storage would continue at existing sites	Small; storage would continue at existing sites	Potential contamination of 0.04 to 0.4 km^2 surrounding each of the 72 commercial and 5 DOE sites
Air quality	Releases and exposures well below regulatory limits (less than 5 percent of limits)	Releases and exposures below regulatory limits; pollutants from vehicle traffic and trains would be small in comparison to other national vehicle and train traffic	No air releases	Releases and exposures well below regulatory limits	Releases and exposures well below regulatory limits	Increases in airborne radiological releases and exposures (potentially exceeding current regulatory limits)
Hydrology (groundwater and surface water)	Water demand well below Nevada State Engineer's ruling on perennial yield (250 to 480 acre-feet[b] per year)	Withdrawal of up to 710 acre-feet[b] from multiple wells and hydrographic areas over 2.5 years	Low-level contamination of groundwater in Amargosa Valley after a few thousand years (estimated concentration would be below drinking water standards)	Small; usage would be small in comparison to other site use	Small; usage would be small in comparison to other site use	Potential for radiological contamination of groundwater around 72 commercial and 5 DOE sites
	Small; minor changes to runoff and infiltration rates; floodplain assessment concluded impacts would be small	Small; minor changes to runoff and infiltration rates; additional floodplain assessments would be performed in the future as necessary	Small; minor changes to runoff and infiltration rates	Small; minor changes to runoff and infiltration rates	Small; minor changes to runoff and infiltration rates	Potential for radiological releases and contamination of drainage basins downstream of 72 commercial and 5 DOE sites (concentrations potentially exceeding current regulatory limits)

Table S-1. Impacts associated with the Proposed Action and No-Action Alternative (page 2 of 4).

Resource area	Proposed Action			No-Action Alternative		
	Short-term (through closure, about 100 years)		Long-term (after closure, about 100 to 10,000 years)	Short-term (100 years)	Long-term (100 to 10,000 years)	
	Repository	Transportation			Scenario 1	Scenario 2
Biological resources and soils	Loss of about 3.5 km^2 of desert soil, habitat, and vegetation; adverse impacts to threatened desert tortoise (individuals, not the species as a whole); reasonable and prudent measures to minimize impacts; impacts to other plants and animals and habitat small; wetlands assessment concluded impacts would be small	Loss of 0 to about 20 km^2 of desert soil, habitat, and vegetation for heavy-haul routes and rail corridors; adverse impacts to threatened desert tortoise (individuals, not the species as a whole); reasonable and prudent measures to minimize impacts; impacts to other plants and animals and habitat small; additional wetlands assessments would be performed in the future as necessary	Slight increase in temperature of surface soil directly over the repository for 10,000 years resulting in a potential temporary shift in plant and animal communities in this small area (about 8 km^2)	Small; storage would continue at existing sites	Small; storage would continue at existing sites	Potential adverse impacts at each of the 77 sites from subsurface contamination of 0.04 to 0.4 km^2
Cultural resources	Repository development would disturb about 3.5 km^2; damage to and illicit collecting at archaeological sites; programs in place to minimize impacts; opposing Native American viewpoint	Loss of 0 to about 20 km^2 of land disturbed for new transportation routes; damage to and illicit collecting at archaeological sites; programs in place to minimize impacts; opposing Native American viewpoint	Potential for limited access into the area; opposing Native American viewpoint	Small; storage would continue at existing sites; limited potential of disturbing sites	Small; storage would continue at existing sites; limited potential of disturbing sites	No construction or operation activities; no impacts
Socioeconomics	Estimated peak employment of 1,800 occurring in 2006 would result in less than a 1 percent increase in direct and indirect regional employment; therefore, impacts would be low	Employment increases would range from less than 1 percent to 5.7 percent (use of intermodal transfer station or rail line in Lincoln County, Nevada) of total employment by county; therefore, impacts would be low	No workers, no impacts	Small; population and employment changes would be small compared to totals in the regions	Small; population and employment changes would be small compared to totals in the regions	No workers; no impacts
Occupational and public health and safety						
Public						
Radiological (LCFs[c])						
MEI[c]	1.9×10^{-5} to 5.1×10^{-5}	1.6×10^{-4} to 1.2×10^{-3}	1.9×10^{-8} to 4.4×10^{-5}	4.3×10^{-6}	1.3×10^{-6}	(d)
Population	0.14 to 0.41	3 to 18	5.5×10^{-5} to 5.3×10^{-4}	0.41	3	3,300[e]
Nonradiological	Exposures well below regulatory limits	Exposures below regulatory limits; pollutants from vehicle traffic and trains	Exposures well below regulatory limits or guidelines	Exposures well below regulatory limits or guidelines	Exposures well below regulatory limits or guidelines	Increases in releases of hazardous substances in the spent nuclear fuel and high-level radioactive waste and exposures to the public

Table S-1. Impacts associated with the Proposed Action and No-Action Alternative (page 3 of 4).

Resource area	Proposed Action			No-Action Alternative		
	Short-term (through closure, about 100 years)		Long-term (after closure, about 100 to 10,000 years)	Short-term (100 years)	Long-term (100 to 10,000 years)	
	Repository	Transportation			Scenario 1	Scenario 2
Occupational and public health and safety (continued)						
Workers (involved and noninvolved)						
Radiological (LCFs)	3 to 4	3 to 11	No workers, no impacts	16	12	No workers, no impacts
Nonradiological fatalities (includes commuting traffic fatalities)	1 to 2	11 to 16[f]	No workers, no impacts	9	1,080	No workers, no impacts
Accidents						
Probability (frequency per year)	8.6×10^{-7} to 1.1×10^{-2}	1.4×10^{-7} to 1.9×10^{-7}	No credible accidents	3.2×10^{-6}	3.2×10^{-6}	3.2×10^{-6}
Public						
Radiological (LCFs)						
MEI	2.9×10^{-13} to 2.1×10^{-6}	0.002 to 0.013	Not applicable	No impacts	No impacts	Not applicable
Population	1.0×10^{-11} to 7.8×10^{-5}	0.02 to 0.07	Not applicable	No impacts	No impacts	3 to 13
Workers	For some accident scenarios workers would likely be severely injured or killed	For some accident scenarios workers would likely be severely injured or killed	No workers; no impacts	For some accident scenarios workers would likely be severely injured or killed	For some accident scenarios workers would likely be severely injured or killed	No workers; no impacts
Noise	Impacts to public would be low due to large distances to residences; workers exposed to elevated noise levels – controls and protection used as necessary	Transient and not excessive, less than 90 dBA[g]	No activities, therefore, no noise	Transient and not excessive, less than 90 dBA	Transient and not excessive, less than 90 dBA	No activities, therefore, no noise
Aesthetics	Low adverse impacts to aesthetic or visual resources in the region	Low, temporary, and transient; possible conflict with visual resource management goals for Jean rail corridor	Small; only surface features remaining would be markers	Small; storage would continue at existing sites; expansion as needed	Small; storage would continue at existing sites; expansion as needed	Small; aesthetic value decreases as facilities degrade
Utilities, energy, materials, and site services	Use of materials would be very small in comparison to amounts used in the region; electric power delivery system to the Yucca Mountain site would have to be enhanced.	Use of materials and energy would be small in comparison to amounts used nationally	No use of materials or energy	Small; materials and energy use would be small compared to total site use	Small; materials and energy use would be small compared to total site use	No use of materials or energy

Table S-1. Impacts associated with the Proposed Action and No-Action Alternative (page 4 of 4).

Resource area	Proposed Action: Short-term (through closure, about 100 years) – Repository	Proposed Action: Short-term (through closure, about 100 years) – Transportation	Proposed Action: Long-term (after closure, about 100 to 10,000 years)	No-Action Alternative: Short-term (100 years)	No-Action Alternative: Long-term (100 to 10,000 years) – Scenario 1	No-Action Alternative: Long-term (100 to 10,000 years) – Scenario 2
Management of site-generated waste and hazardous materials	Radioactive and hazardous waste generated would be a few percent of existing offsite capacity; other wastes would be managed offsite and some waste potentially at an onsite landfill	Radioactive and hazardous waste generated would be a few percent of existing offsite capacity; other wastes would be managed offsite and some waste potentially at an onsite landfill	No waste generated or hazardous materials used	Small; waste generated and materials used would be small compared to total site generation and use	Small; waste generated and materials used would be small compared to total site generation and use	No waste generated or hazardous materials used
Environmental justice	No disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint	No disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint	No disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint	No disproportionately high and adverse impacts to minority or low-income populations	No disproportionately high and adverse impacts to minority or low-income populations	Potential for disproportionately high and adverse impacts to minority or low-income populations

a. km^2 = square kilometers; to covert to acres, multiply by 247.1.
b. To convert acre-feet to cubic meters, multiply by 1233.49.
c. LCF = latent cancer fatality; MEI = maximally exposed individual.
d. The maximally exposed individual could receive a fatal dose of radiation within a few weeks to months. Death would be caused by acute direct radiation exposure.
e. Downstream exposed population of approximately 3.9 billion over 10,000 years.
f. As many as 8 of these fatalities could be members of the public; fatalities include commuting traffic fatalities.
g. dBA = A-weighted decibels, a common sound measurement. A-weighting accounts for the fact that the human ear responds more effectively to some pitches than to others. Higher pitches receive less weighting than lower ones.

and high-level radioactive waste was removed. Under the No-Action Alternative, there would be a loss of about 2,500 jobs in the three-county area around Yucca Mountain once reclamation was completed. There would be no short-term socioeconomic impacts at the storage sites under the No-Action Alternative.

The potential long-term (100 to 10,000 years) environmental impacts of the Proposed Action and No-Action Scenario 1 (continued institutional control) would also be small. Under the Proposed Action, there would be virtually no latent cancer fatalities (much less than 1) over 10,000 years. In addition, there would be a potential for minimal impacts to vegetation and animals over the repository area as soil surface temperatures increased. Under the No-Action Scenario 1, there would be about 15 latent cancer fatalities and about 1,000 nonradiological fatalities associated with the construction and replacement of storage facilities, monitoring of facilities, worker commuting, and transportation of construction materials. Small impacts to other resources (for example, socioeconomics, biological resources, utilities and services) would occur.

There would be differences in the potential long-term environmental impacts under No-Action Scenario 2 (no institutional control after 100 years) compared to No-Action Scenario 1. Under No-Action Scenario 2, there would be about 3,300 latent cancer fatalities over 10,000 years as storage facilities across the United States degraded and radionuclides from spent nuclear fuel and high-level radioactive waste reached and contaminated the environment. There would be no fatalities associated with transportation, construction, or operation because those activities would not occur after the loss of institutional control.

CONVERSIONS

METRIC TO ENGLISH			ENGLISH TO METRIC		
Multiply	**by**	**To get**	**Multiply**	**by**	**To get**
Area					
Square meters	10.764	Square feet	Square feet	0.092903	Square meters
Square kilometers	247.1	Acres	Acres	0.0040469	Square kilometers
Square kilometers	0.3861	Square miles	Square miles	2.59	Square kilometers
Concentration					
Kilograms/sq. meter	0.16667	Tons/acre	Tons/acre	0.5999	Kilograms/sq. meter
Milligrams/liter[a]	1	Parts/million	Parts/million[a]	1	Milligrams/liter
Micrograms/liter[a]	1	Parts/billion	Parts/billion[a]	1	Micrograms/liter
Micrograms/cu. meter[a]	1	Parts/trillion	Parts/trillion[a]	1	Micrograms/cu. meter
Density					
Grams/cu. cm	62.428	Pounds/cu. ft.	Pounds/cu. ft.	0.016018	Grams/cu. cm
Grams/cu. meter	0.0000624	Pounds/cu. ft.	Pounds/cu. ft.	16,025.6	Grams/cu. meter
Length					
Centimeters	0.3937	Inches	Inches	2.54	Centimeters
Meters	3.2808	Feet	Feet	0.3048	Meters
Kilometers	0.62137	Miles	Miles	1.6093	Kilometers
Temperature					
Absolute					
Degrees C + 17.78	1.8	Degrees F	Degrees F – 32	0.55556	Degrees C
Relative					
Degrees C	1.8	Degrees F	Degrees F	0.55556	Degrees C
Velocity/Rate					
Cu. meters/second	2118.9	Cu. feet/minute	Cu. feet/minute	0.00047195	Cu. meters/second
Grams/second	7.9366	Pounds/hour	Pounds/hour	0.126	Grams/second
Meters/second	2.237	Miles/hour	Miles/hour	0.44704	Meters/second
Volume					
Liters	0.26418	Gallons	Gallons	3.78533	Liters
Liters	0.035316	Cubic feet	Cubic feet	28.316	Liters
Liters	0.001308	Cubic yards	Cubic yards	764.54	Liters
Cubic meters	264.17	Gallons	Gallons	0.0037854	Cubic meters
Cubic meters	35.314	Cubic feet	Cubic feet	0.028317	Cubic meters
Cubic meters	1.3079	Cubic yards	Cubic yards	0.76456	Cubic meters
Cubic meters	0.0008107	Acre-feet	Acre-feet	1233.49	Cubic meters
Weight/Mass					
Grams	0.035274	Ounces	Ounces	28.35	Grams
Kilograms	2.2046	Pounds	Pounds	0.45359	Kilograms
Kilograms	0.0011023	Tons (short)	Tons (short)	907.18	Kilograms
Metric tons	1.1023	Tons (short)	Tons (short)	0.90718	Metric tons
ENGLISH TO ENGLISH					
Acre-feet	325,850.7	Gallons	Gallons	0.000003046	Acre-feet
Acres	43,560	Square feet	Square feet	0.000022957	Acres
Square miles	640	Acres	Acres	0.0015625	Square miles

a. These widely used conversions are only valid under specific temperature and pressure conditions.

METRIC PREFIXES

Prefix	Symbol	Multiplication factor		
exa-	E	1,000,000,000,000,000,000	=	10^{18}
peta-	P	1,000,000,000,000,000	=	10^{15}
tera-	T	1,000,000,000,000	=	10^{12}
giga-	G	1,000,000,000	=	10^{9}
mega-	M	1,000,000	=	10^{6}
kilo-	k	1,000	=	10^{3}
deca-	D	10	=	10^{1}
deci-	d	0.1	=	10^{-1}
centi-	c	0.01	=	10^{-2}
milli-	m	0.001	=	10^{-3}
micro-	µ	0.000 001	=	10^{-6}
nano-	n	0.000 000 001	=	10^{-9}
pico-	p	0.000 000 000 001	=	10^{-12}